Bolt Beranek and Newman Inc.

NASA Contractor Report 159167

(NASA-CR-159167) INITIAL STUDY OF THE IMMEDIATE ANNOYANCE OF AIRCRAFT NOISE AS A FUNCTION OF TIME OF DAY (Bolt, Beranek, and Newman, Inc.) 108 p [redacted]

[redacted]

Unclas
B3/45 47699

Initial Study of the Immediate Annoyance of Aircraft Noise as a Function of Time of Day

Richard D. Horonjeff
Sherri R. Teffeteller

Bolt Beranek and Newman Inc.
Canoga Park, CA 91305

Contract NAS1-15467
April 1980

[redacted]

NASA
National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665
AC 804 827-3966

NASA Contractor Report 159167

Initial Study of the Immediate Annoyance of Aircraft Noise as a Function of Time of Day

Richard D. Horonjeff
Sherri R. Teffeteller

Bolt Beranek and Newman Inc.
Canoga Park, CA 91305

Contract NAS1-15467
April 1980

~~For U.S. Government Agencies Only~~

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665
AC 804 827-3966

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

I. INTRODUCTION

A. Purpose

Several major metrics of twenty-four hour noise exposure incorporate a weighting factor intended to account for presumed differences in the acceptability of noise intrusions at different times of day. Although differing somewhat in form, the metrics divide the twenty-four hour day into two or more periods over which a constant weighting factor is applied. The weighting factor is a decibel-like number added arithmetically to a measured sound level. Thus, sounds at some times of day are treated as though they were noisier than they really were prior to cumulation over a twenty-four hour period into a single number rating of daily noise exposure.

The essential differences between cumulative indices are 1) the number of periods into which the twenty-four hour period is divided; 2) the time boundaries of the periods; and 3) the magnitude of the weighting factor for each period.

The overall goal of the current study was the development of several operational definitions for the relative annoyance of noise intrusions at different times of day and the application of these definitions to a real time survey of aircraft noise intrusions in peoples' homes. The results of the study would provide data for future selection of time of day weighting factors.

B. Report Organization

Section II provides a brief historical account of the use of time of day weighting factors in twenty-four hour noise metrics. The reader interested in an overview of the study need read only the introductory paragraph of Sections III, IV, and V before reading the Discussion and Conclusions in Sections VI and VII. Section III describes the method used to obtain data which in turn was analyzed by the procedure described in Section IV. Results are presented in Section V, followed by a discussion (including possible sources of error) in Section VI. Section VII provides a number of conclusions regarding procedural and substantive aspects of the study. The appendices provide additional information on data acquisition equipment, instructions to respondents, and detailed noise environment statistics.

II. BACKGROUND

Rosenblith et al. originated the concept of a nighttime adjustment to noise exposure in 1953 with a commonsensical argument to the effect that nighttime noise exposure is not masked by ambient noise to the same degree as daytime exposure. An entirely ad hoc "correlation" of -1 in the level rank procedure was suggested to account for this effect. This adjustment was tantamount to a five decibel differential between "daytime only" and round-the-clock or nighttime noises (Galloway, 1977).

When incorporated into Community Noise Ratings (CNR) and Noise Exposure Forecasts (NEF) rating methods ten years later, the five decibel correction was doubled on the basis of an argument constructed from the 1961 Heathrow Airport survey. It was claimed that "a reduction of 17 NNI units was required to achieve the same acceptability for nighttime aircraft operations as for day operations" (Galloway, 1977). Seventeen NNI units can be converted to eleven units on the CNR or NEF scales by assumption of a fixed noise level. Ollerhead (1978) has noted the logical weaknesses in this argument.

Other methods of assessing the acceptability of aircraft noise exposure have subsequently adopted adjustments of five to fifteen decibels to account for time of day effects during various periods of day, evening, and night.

The necessity of a nighttime penalty for aircraft noise has become increasingly questioned in the last few years. The current rationale for the ten dB nighttime penalty common to many integrated measures of aircraft and community noise is largely conjectural. The penalty is based more on intuition than upon empirical evidence. Information from field studies can hardly be said to support a penalty at all, since the usual drop in noise levels at night makes it difficult to discriminate differences in effect from differences in exposure.

Conventional studies of nighttime penalties have failed to substantiate the need for a nighttime penalty. A social survey conducted by BBN (Fidell and Jones, 1976) at Los Angeles International Airport demonstrated that a late night curfew had essentially no short term effect on the annoyance or self-reported sleep quality of the people who were most directly affected by the change in operations. In fact, most people failed to notice the cessation of nighttime landing noise.

Nighttime penalties currently imposed on aircraft noise are inferred from the data of investigations using four different methodologies: case studies, social surveys, laboratory studies of sleep, and artificial exposure experiments. It is entirely possible that nighttime penalties may be the result of procedural and substantive flaws of these disparate studies rather than an indication of the need for such penalties.

Consider, for example, case studies of community reaction to aircraft noise exposure (e.g., Stevens et al. (1955)). Case studies tend to focus on investigations of complaints resulting from aircraft noise, thus missing the bulk of the effects of noise exposure. Statistically, the results of such investigations cannot be generalized to larger populations due to the limited sample involved. Also, the author's opinions usually serve as the basis for estimating the magnitude of the nighttime penalty, without quantitative foundation.

Social surveys have also been used to investigate community reaction to aircraft noise exposure. These surveys often include questions about respondents' attitudes toward noise exposure at night. Inferences about nighttime penalties drawn from social surveys often lack logical rigor and statistical validity. First, analyses of social survey data do not usually account for substantial demographic differences between daytime and nighttime populations of neighborhoods. Thus, inferences drawn from social survey data combine the opinions of people who have different degrees of familiarity with daytime neighborhood noise conditions. The result could possibly be a bias in favor of a nighttime penalty.

Another basic deficiency of social survey information is its lack of immediacy or specificity. Social surveys never directly measure the actual effects of aircraft noise exposure at different times of the day, but rather rely on delayed self-reports of respondents. A large but unknown number of factors intervene between the direct experience of annoyance or activity interference from aircraft noise intrusions and subsequent interviewing.

A final problem of inferring time of day factors from social survey data is the high degree of arguable statistical treatment needed to estimate their magnitude from the response data. Often there is little justification for the elaborate statistical treatments to which the data are subjected (factor analysis, scale construction, etc.). In many cases alternative statistical treatments of the same data, equally plausible and reasonable, support different conclusions about the necessity and magnitude of nighttime penalties.

Laboratory studies of the effects of noise exposure on sleep also suffer from a number of deficiencies. First, inferences must be drawn from a small sample of test subjects to support generalizations to the real world. Second, the obvious artificiality of sleeping in a laboratory rather than in familiar quarters is never adequately resolved. Perhaps most importantly, it is not at all clear how the relative effects of daytime and nighttime exposure can be inferred from a study of nighttime effects alone.

These and other deficiencies of data produced by conventional studies of nighttime penalties suggested the need for an innovative approach in the current study. A technique was developed for real time measurement of annoyance from aircraft noise during morning, afternoon, evening and night periods in residential settings. The procedure is described in detail in the following section.

III. METHOD

A. Overview

People in their own homes rated their annoyance to individual aircraft flyovers for periods of two to four weeks. Simultaneous monitoring of aircraft sound levels permitted correlation between judged annoyance and outdoor aircraft sound levels, as explained in Section IV of this report. In addition, a post-study questionnaire soliciting demographic and attitudinal information was administered to all test participants.

B. Annoyance Response Measure

A consistent measure of daytime and nighttime annoyance responses was sought in order to avoid the problem of "comparing apples with oranges", thus unnecessarily complicating the relative assessment of daytime and nighttime aircraft noise intrusions. The technique employed for attaining these responses was similar to one used successfully by Fidell et al. (1973) to measure real time annoyance in neighborhoods exposed to aircraft noise. The method has since independently been reconfirmed by Purcell and Thorne (1977).

The data collection apparatus consisted of four pieces of equipment: 1) a simple four-digit mechanical counter attached to a nylon waist strap; 2) an inexpensive digital wristwatch; 3) a set of postcards for daily reporting of mechanical counter readings; and 4) a set of detailed test instructions regarding use of the equipment. A copy of the test instructions and sample postcards for the two airports are shown in Appendix A.

The mechanical counter served as the annoyance judgment manipulandum. The counter was equipped with a single button which incremented the count by one each time it was depressed. The reset knob was removed so that the count could not be unintentionally altered. The nylon waist strap was provided so the counter could be conveniently carried by the participant.

Test participants were instructed to press the button on the counter once, whenever they heard an aircraft flyover that they would rather not have heard at the moment it occurred. With this guideline, participants were free to develop their own criteria for deciding whether a particular aircraft noise intrusion was "annoying" or "not annoying".

Participants were also instructed to place the counter beneath the pillow upon retiring in the evening to facilitate nighttime access. They were asked to push the same push button if they were awakened during the night, regardless of the reason. These instructions were intended to bias an inferred nighttime threshold upward, and accentuate a nighttime "penalty". This technique was successfully used in a behavioral awakening experiment (Horonjeff et al., 1978). The results of this study indicated that only a low number of spontaneous awakenings (less than one per night) could not be attributed to a moderate to high level transient noise intrusion.

Participants were instructed to transfer the number showing on their counter to the pre-printed postcard supplied for each day of the study. They were required to copy the counter total onto the postcard log whenever convenient throughout the day, but at a minimum upon awakening, at lunchtime, at dinnertime, and upon retiring. Participants were also requested to transcribe the time of day to the postcard from the digital wristwatch. Times were transcribed to the nearest minute, although the wristwatches were initially set to match the local telephone dial-up time to the nearest two seconds. The digital wristwatches were also synchronized to the clock in the noise monitor. In addition, participants were instructed to log the times when they were away from home so that aircraft they did not hear could be omitted from data analysis.

Postcards were mailed to BBN's Los Angeles office daily to constantly monitor the participants' progress. Test participants were contacted by telephone at frequent intervals throughout the entire data collection period to determine whether any problems existed and to reaffirm the seriousness of interest in their participation.

In addition to the individual annoyance responses gathered from the participants, brief pre- and post-study questionnaires were administered. The questionnaires are also included in Appendix A. The questionnaires solicited demographic information as well as general feelings of annoyance to aircraft noise both during the study and over the past year.

C. Noise Measures

Cost efficiency dictated that the long term measurement of the noise environment be performed by an unattended monitoring system capable of recording single event sound levels and time of occurrence for each noise intrusion. One monitor system was centrally located in each of the four neighborhoods used in this study.

The BBN Model 704 employed in this study reports the maximum A-weighted sound level, the sound exposure level (SEL), and time of occurrence of each noise intrusion which exceeds a preset threshold level. Thresholds were set at 69, 66, 72, and 75 dB(A) for Sites A, B, C, and D, respectively. The monitor clock has a resolution of 0.1 minute and was set and maintained to match local dial-up telephone time to an accuracy of ± 0.1 minute. Instrument calibration was performed daily at the Atlanta sites and every other day at the Burbank locations. Sound level calibration was maintained to within ± 0.5 dB. Further details of the monitor systems are presented in Appendix B.

D. Sites

Sites were chosen near two airports located in Burbank, California, and Atlanta, Georgia. The first site, Burbank-Glendale-Pasadena Airport (BUR), was selected primarily to check the data collection and subject selection techniques.

The Burbank Airport is located approximately 20 miles north of downtown Los Angeles. The airport serves short and medium range destinations with approximately 85 commercial jet operations per day. Aircraft types are almost exclusively B-727's, B-737's, and DC-9's. Several fixed base operators are responsible for numerous light propeller aircraft operations and a few business and jet operations. Commercial operations commence between 7 and 8 a.m.

and cease between 10 and 11 p.m. There are, however, occasional non-commercial night operations.

Figure 1 shows the location of the airport, the approximate departure path from Runway 15 (which handles over 91% of all commercial operations), and the locations of test participant communities. Community A, located approximately 1.8 miles (3 km) from brake release, experiences 40 to 45 commercial aircraft departures per day with maximum A-weighted sound levels of 95 to 105 dB and sound exposure levels (SEL) of 101 to 111 dB. The L_{dn} of this community was estimated at 75 to 80 dB.

In contrast, Community B, located approximately .9 miles (1.4 km) to the side of the departure path experiences maximum levels of only 80 to 90 dB(A) and SEL's of 89 to 98 dB. The L_{dn} in Community B was estimated to be 57 to 62 dB. Both areas are exposed to the same overflights. Houses in both areas are single family residences of similar age and construction.

The airport at which the majority of data collection took place was the Atlanta-Hartsfield International Airport in Atlanta, Georgia. This airport was selected because of the relatively high percentage of nighttime flights (15%) and communities exposed to aircraft noise located fairly close to the airport. Figure 2 shows the location of the two communities selected for the noise survey in relation to the airport and relevant flight paths. Community C is approximately 0.3 miles (.4 km) south of the extended centerlines of Runways 9L/27R and 9R/27L. The site was selected to fall within L_{dn} 75 to 80 dB. Maximum A-weighted sound levels range from 77 to 102 and sound exposure levels range from

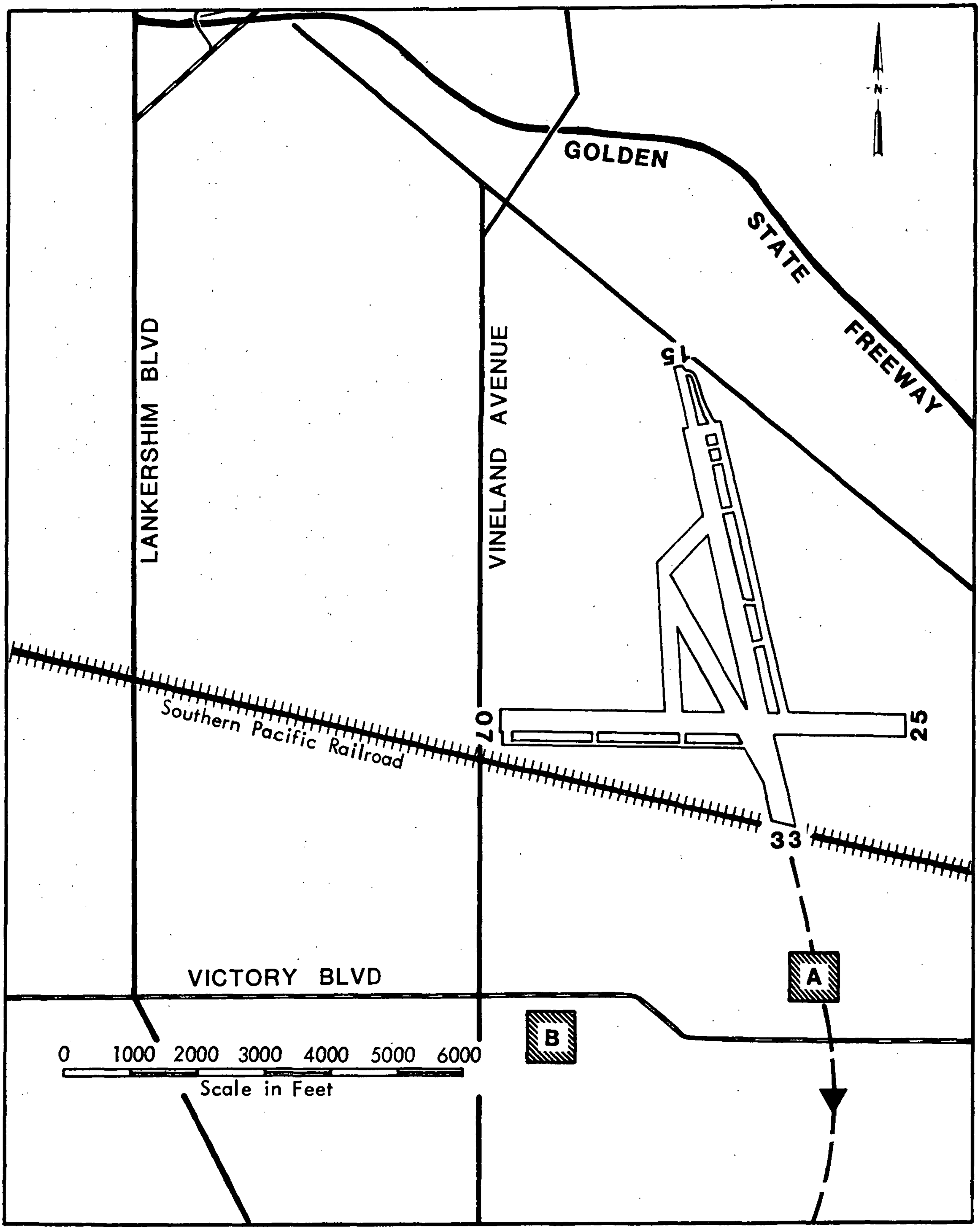


FIGURE 1. NOISE SURVEY AREAS - BURBANK, CA.

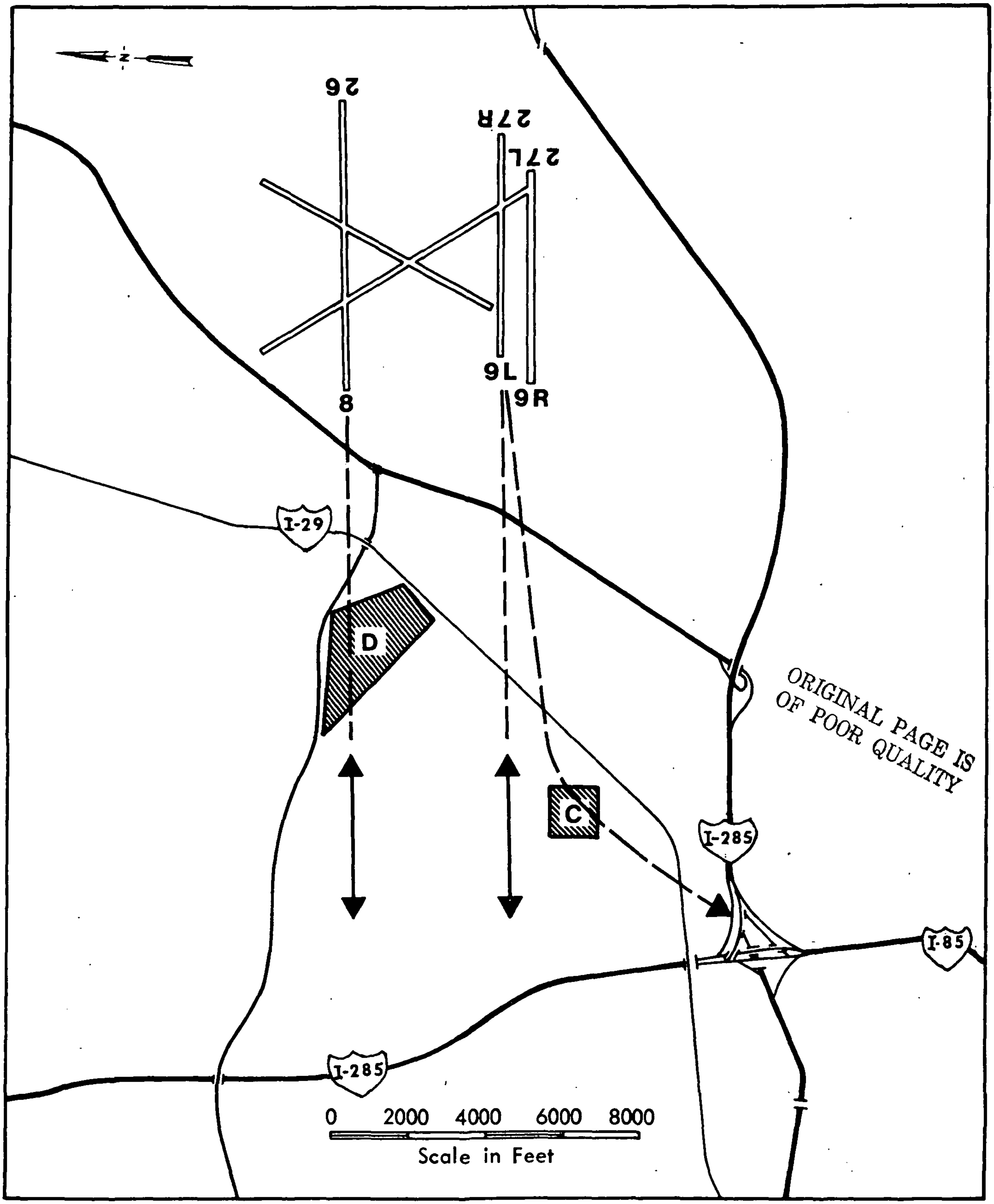


FIGURE 2. NOISE SURVEY AREAS - ATLANTA, GA.

79 to 108. Community D is located beneath the extended centerline of Runway 8/26. The L_{dn} values were estimated to range from 80 to 85 dB. Maximum A-weighted sound levels range from 77 to 106 and sound exposure levels range from 79 to 112. Both communities experience an average of 350 overflights per day of which half are departures and half are landings.

E. Test Participants

Test participants were chosen from the residential areas surrounding the airports shown in Figures 1 and 2. They were obtained by door-to-door canvassing. Only people who spent large amounts of time in their home (i.e., retired and non-working people) were recruited. Persons whose daily schedules caused them to be away from their residence for large portions of the day were excluded so that attention could be concentrated on judgments of aircraft noise heard in the same location at different times of the day.

The sixteen participants from the Hollywood-Burbank area included fourteen women and two men. The mean age for the women was 41 years while the two men had an average age of 66 years. Six out of the sixteen households (38%) had at least one or more children under the age of 10 years. Test participants came from families with an average annual income of $19,400. The average length of residence in their present home was 11.4 years.

The residents in the Atlanta, Georgia area, near the Atlanta-Hartsfield International Airport, included 19 women and 11 men whose average ages were 53 and 59, respectively. Average annual income was $17,900. Only 20% of the test participants had one or more children under the ages of ten. The average length of residence in their current homes was 13.7 years.

IV. ANALYSIS

A. Overview

The annoyance and noise data were analyzed in three different ways, corresponding to three models of human performance. All three models sought to determine whether or not aircraft noise intrusions of equal magnitude were judged more annoying at some times of the day than at others by people routinely exposed to aircraft noise in their residences over a twenty-four hour period.

B. Rationale

The general purpose of this study was to explore the extent to which peoples' immediate annoyance judgments of aircraft flyovers in a residential setting vary with time of day. Three assumptions were made in analyzing these data:

1) All other things being equal, the degree of annoyance associated with a single aircraft noise intrusion increases monotonically with sound level;

2) People register annoyance with a button push when a level-related criterion of annoyance is exceeded; and

3) The probability of an annoyance response can be described by a psychometric function relating the behavioral response to the single event sound level.

Figure 3 plots hypothetical probabilities that an aircraft noise intrusion will be judged "annoying" versus the outdoor single event sound level. Although many measures of single event sound level exist, practical considerations limited the choice of noise metrics in the current study to two types of measures: 1) the

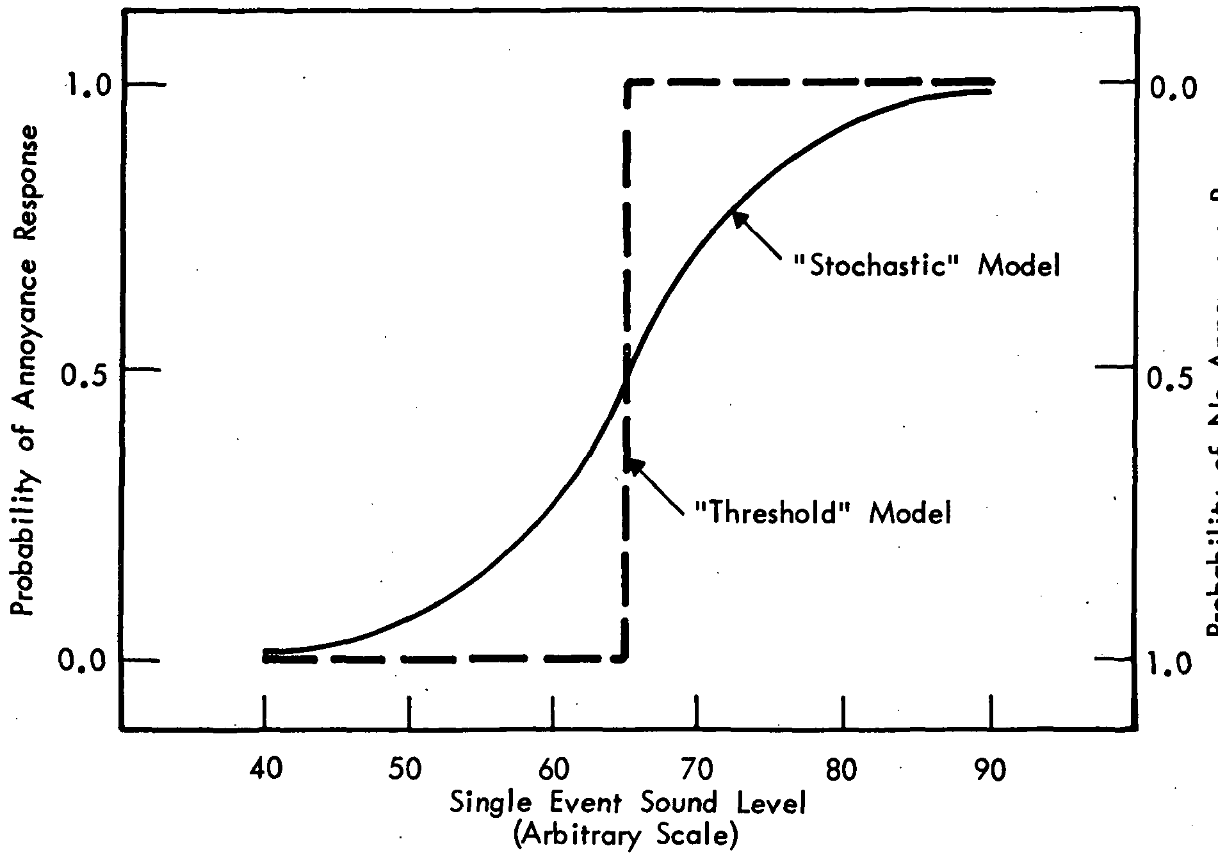


FIGURE 3. HYPOTHETICAL PSYCHOMETRIC FUNCTIONS RELATING ANNOYANCE AND SINGLE EVENT SOUND LEVEL

maximum A-weighted sound level, and 2) the sound exposure level (SEL). Selection of these measures was dependent upon available noise monitor instrumentation, described more fully in Appendix B of this report.

The solid curve in Figure 3 represents a probabilistic (stochastic) model which asserts that an individual's annoyance arising from a single event cannot be predicted with certainty. It does assert, however, that the probability of annoyance increases with sound level. The curve shown is asymptotic to probabilities of zero and one, although the model does not require that this be the case.

The dotted lines in Figure 3 represent a deterministic (threshold) model of annoyance, which asserts that annoyance invariably occurs when exposure exceeds some criterion. The threshold model is in fact a special case of the stochastic model with an infinitely steep slope.

Individual differences in sensitivity to noise will cause psychometric functions for annoyance to differ between individuals. Differences in daily activities may also affect an individual's psychometric function to some extent. However, correlation of annoyance judgments and single event sound levels over periods of one to two weeks can be expected to yield reasonably stable estimates of an individual's psychometric function for aircraft noise annoyance.

Time of day effects may be inferred by comparing separate functions for two or more periods of the day. Figure 4 shows hypothetical functions for two periods of the day. In this example

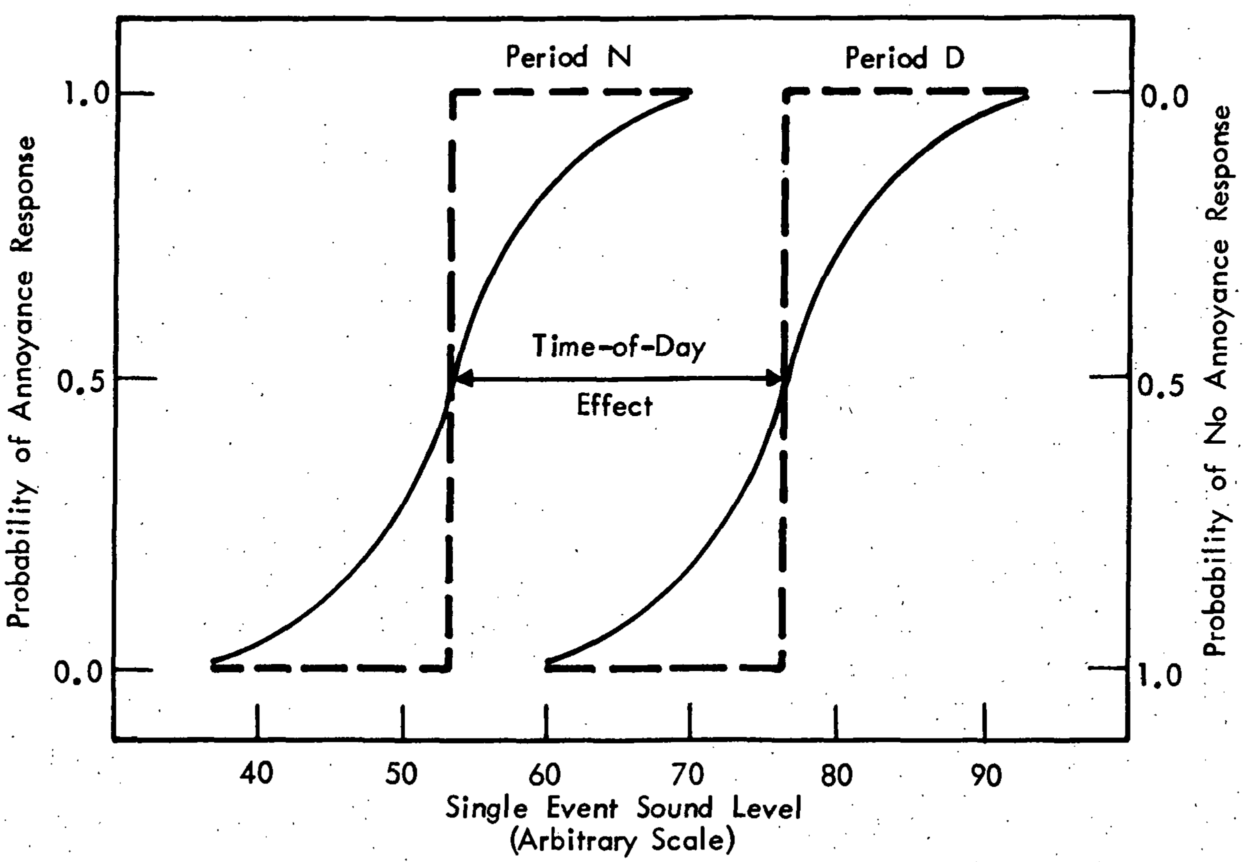


FIGURE 4. HYPOTHETICAL PSYCHOMETRIC FUNCTIONS FOR TWO PERIODS OF THE DAY

the function for period N is displaced lower in level from that of period D. From this condition it is inferred that noise intrusions during period N must (on average) be lower in level than during period D to be judged equally annoying. The amount by which the level must be lower during period N is determined by the horizontal displacement of the two functions, which quantifies the time of day effect in decibels. This approach allows time of day effects to be estimated separately for each participant. Individual opinions may then be averaged to estimate population trends.

The choice of annoyance model (threshold or stochastic) has strong implications regarding cost, efficiency and ease of data acquisition and analysis. While the stochastic model is certainly more aesthetically appealing (and probably more realistic), it is also more costly and difficult to implement. Development of psychometric functions under this model requires a one-to-one correlation of aircraft sound levels and annoyance judgments for every aircraft overflight. After thousands of overflights the proportion of overflights eliciting an annoyance response may be determined as a function of sound level. The difficulty and cost of acquiring the annoyance data in a form able to be correlated with sound level measurements was beyond the scope of this project.

Choice of the threshold model alleviates most of the tedious correlation problems and is functionally equivalent to the stochastic model if the following two conditions are met: 1) the slope of an individual's true psychometric function is invariant with time of day, and 2) the distribution of aircraft sound levels is also independent of time of day (note that this requirement deals with relative proportions and not absolute numbers of events).

Although there is no convenient way of confirming the existence of the first condition, it is not an unreasonable assumption. Satisfaction of the second condition is dictated primarily by the mix of aircraft flight track utilization, and to a lesser extent, atmospheric absorption. If the mix of aircraft and percentage utilization of pertinent arrival and departure paths are independent of time of day, it can reasonably be assumed that the second condition is satisfied. These factors must be explicitly considered during the site selection process with a post hoc examination of measured noise levels to verify that the second condition is met.

The major advantages of the threshold model lie in its cost effectiveness and simplicity of data collection and analysis. The threshold model eliminates the need for one-to-one correlations of annoyance judgments and measured sound levels. Instead, correlations are performed by time blocks.

Consider the following example. Participant A reports that she was annoyed by aircraft 20 times between 9:15 a.m. and 11:30 a.m. on a particular day, but the exact times of each annoyance are unknown. Assuming she is a threshold detector, those 20 responses must have been to the 20 noisiest aircraft during the same block of time. If noise monitoring instrumentation is simultaneously recording the sound level and time of occurrence of all significant noise intrusions, then the best estimate of Participant A's threshold for that period is the level which is just exceeded by the 20 noisiest events, but not exceeded by the 21st noisiest event. A straightforward search of noise monitor records produces the threshold value.

Note the following contingencies: 1) the time of day need not be recorded each time the participant is "annoyed"; 2) the participant needs to maintain only a running total of the number of instances of annoyance, and tabulate this number at intervals throughout the day; 3) time correlation between annoyance responses and noise monitor data can be accomplished by supplying participants with an inexpensive digital timepiece pre-synchronized to the noise monitor clock; 4) a single, centrally located noise monitor can be used to correlate with a number of nearby participants; and 5) the noise monitor does not need to record low sound level events since these are likely to be well below the individuals' annoyance threshold.

The major requirement of the noise monitor unit is that recorded noise intrusions whose sound levels exceed the respondent's annoyance threshold be unarguably the result of aircraft flyovers and not some other local noise source. Judicious selection of a site for the instrument generally avoids such problems. The noise monitor sites used in this study were in single family residential neighborhoods whose rear years had adequate structure attenuation of street traffic noise. The chance of recording non-aircraft sources of a magnitude equal to that produced by passing aircraft was further reduced by avoiding known local noise sources such as barking dogs, air conditioning units, etc. Note that contamination of the data below the individual's annoyance "threshold" sound level has no effect on the inferred threshold value. That is, neither the recording of occasional low level non-aircraft events or the loss of low level aircraft intrusions would influence the count of the N noisiest flights. Such contamination does influence post-hoc comparison of aircraft sound level distributions, however, and the siting of the noise monitor in quiet areas is important in this regard. Appendix C provides a detailed description of the noise environment in each of the four communities used in the study. The figures show that the relative distribution of sound levels from individual events remains essentially the same over the four different time periods of the day.

C. Data Processing

Participant annoyance data and noise monitor information were transferred to computer punchcard for machine analysis. A digital computer performed the tedious task of correlating noise and annoyance data to determine the differences in sound level necessary to make aircraft noise intrusions equally annoying at different times of day.

Noise exposure and response information files for each test participant were created on a large digital computer. Various analyses were conducted by merging the two sets of files in different ways. A response file was composed of several hundred chronological entries, each consisting of a date, time, and mechanical counter total. Four sound level files (one for each community) were composed of thousands of chronological entries, each consisting of a date, time, maximum A-level, and sound exposure level of a single aircraft noise intrusion. These files were manipulated by software specially prepared for a Control Data Cyber 175 computer.

The computer program merged the appropriate noise data file with each respondent's annoyance data file. The computer program determined which noise intrusions occurred between any two counter total reports from the dates and times of the response records. The program divided the day into four different time periods (morning, afternoon, evening and night) and performed three different analyses for each period, corresponding to three hypotheses regarding human performance. These ultimately led to three separate estimates for the time of day effects.

The noise level descriptors arose from the three hypotheses about how individuals performed their judgment tasks. Two hypotheses explored annoyance "thresholds" on the assumption that a person has a threshold for aircraft noise above which he is annoyed enough to push a counter button and below which he does not push the button. Noise levels were measured in maximum A-weighted sound levels (SLA) and sound exposure levels (SEL). A third descriptor was the equivalent SEL of an aircraft overflight necessary to elicit one counter response (unit annoyance) from an individual. Details of the descriptors follow.

1. The SEL Annoyance Threshold

This hypothesis asserts that people judge annoyance based on the sound exposure level (SEL) of the noise intrusion. In doing so people act as annoyance threshold detectors; that is, they advance their annoyance counter only if the SEL of a flyover exceeds their internal annoyance threshold.

The computer analysis estimated the annoyance over the entire period of participation for each individual during each of four periods of the day. Figure 5 provides an example of how the analysis was performed. In this example the SEL threshold for the morning time period was sought. For the sake of brevity, a hypothetical field study of only two days' duration is shown.

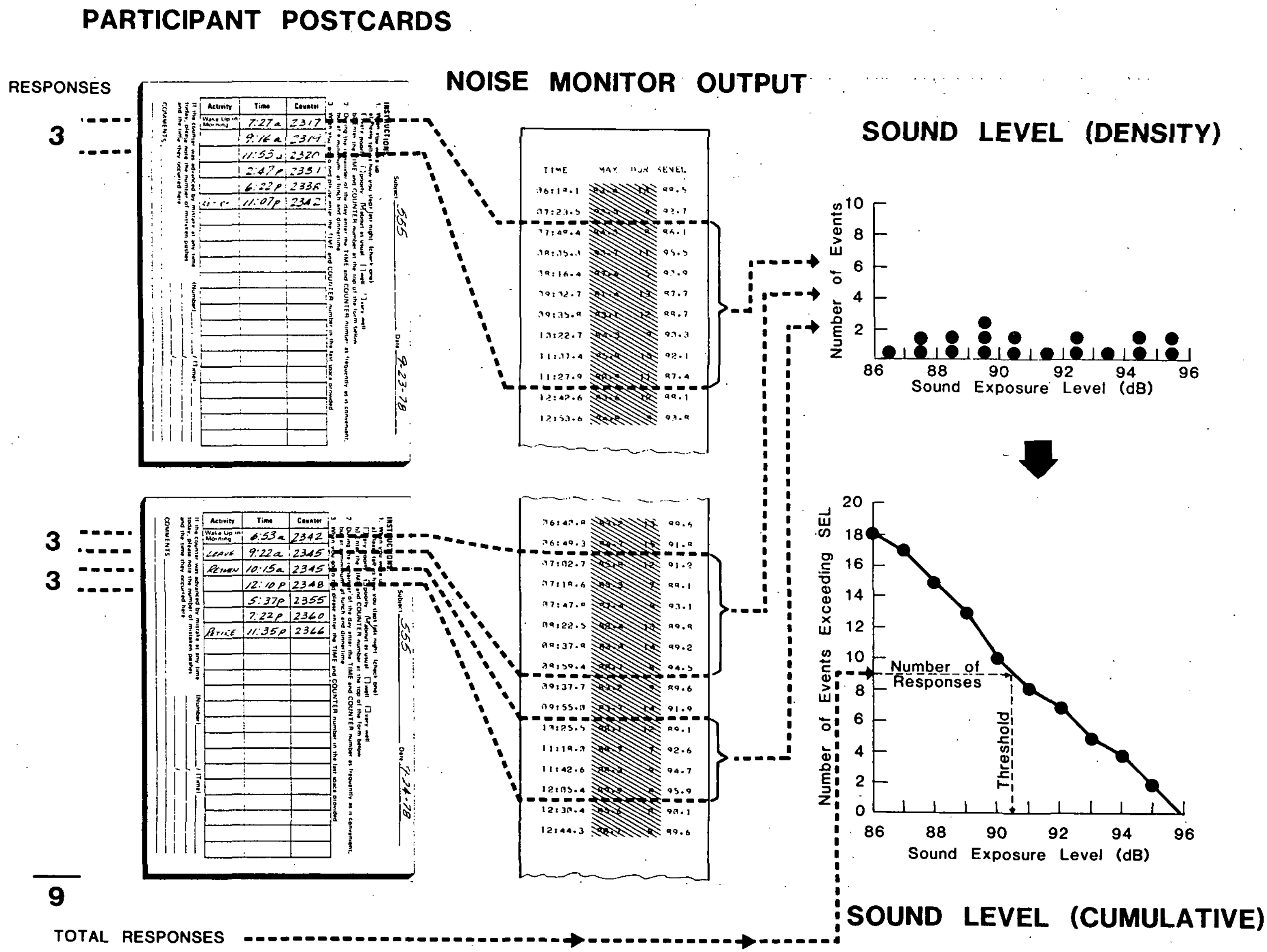


FIGURE 5. PROCEDURE FOR ESTIMATING ANNOYANCE THRESHOLD

During the study the participant completed two daily annoyance postcard logs (shown at the left of the figure). A listing of noise intrusions simultaneously recorded by a nearby noise monitor lies to the right of the postcards. Noise intrusions outside the morning time period are not shown since they are not used in the morning analysis.

Responses were ascribed to the morning period if it could be uniquely determined that they occurred no earlier than 6:30 a.m. and no later than 12:30 p.m. Over the two day study the participant logged nine annoyance responses (three during the first day and six on the second day). Using the exact times reported by the participant , all SEL's within the bounds defined by the participant were extracted from the noise monitor data and used to generate a single event density function (with a resolution of one dB). The density function is shown to the right of the noise monitor data. Note that on the second day the respondent reported being away from his residence for a brief period of time and that noise intrusions during this time were not included in the density function (since they were presumably not heard by the participant). Also note that the only usable morning data for the second day would have been that logged between 6:53 and 9:22 a.m. if the participant had failed to make the entry at 12:10 p.m.

Finally, the SEL density was converted to a cumulative function (number of events exceeding a given sound level). This function was entered along with the number of annoyance responses to determine the threshold value. In this manner, thresholds were estimated separately for four periods of the day for each respondent. Differences in level for the same annoyance between any two periods was determined by taking the difference in threshold values. These differences were averaged over all participants.

2. The SLA Annoyance Threshold

This hypothesis differs from the SEL hypothesis in that people are assumed to base their annoyance judgments on the maximum A-weighted sound level rather than on an integrated measure. This analysis was performed in an identical manner to the SEL annoyance threshold with the exception that the noise monitor data file was searched for the maximum A-level of each noise intrusion rather than the SEL. Computations of individual thresholds, differences, and means were performed as described above.

3. Unit Annoyance SEL

A tacit assumption of independence was made in the two threshold analyses described above. That is, it was assumed that the judged annoyance of a given noise intrusion was not influenced by prior intrusions. The unit annoyance SEL hypothesis made the opposite assumption by asserting that people act as energy accumulators. As such the cumulative number of annoyance responses was assumed to be a function of the total SEL (energy sum of individual event SEL's) over long periods of time. The expectation was that increasing numbers of annoyance responses were elicited by greater and greater sound energy, either due to greater numbers of noise intrusions or intrusions of higher level. This hypothesis did not assume a threshold detector or that judgments about sequential noise intrusions were independent. The analysis was relatively straightforward, and is shown pictorially in Figure 6.

ORIGINAL PAGE IS OF POOR QUALITY

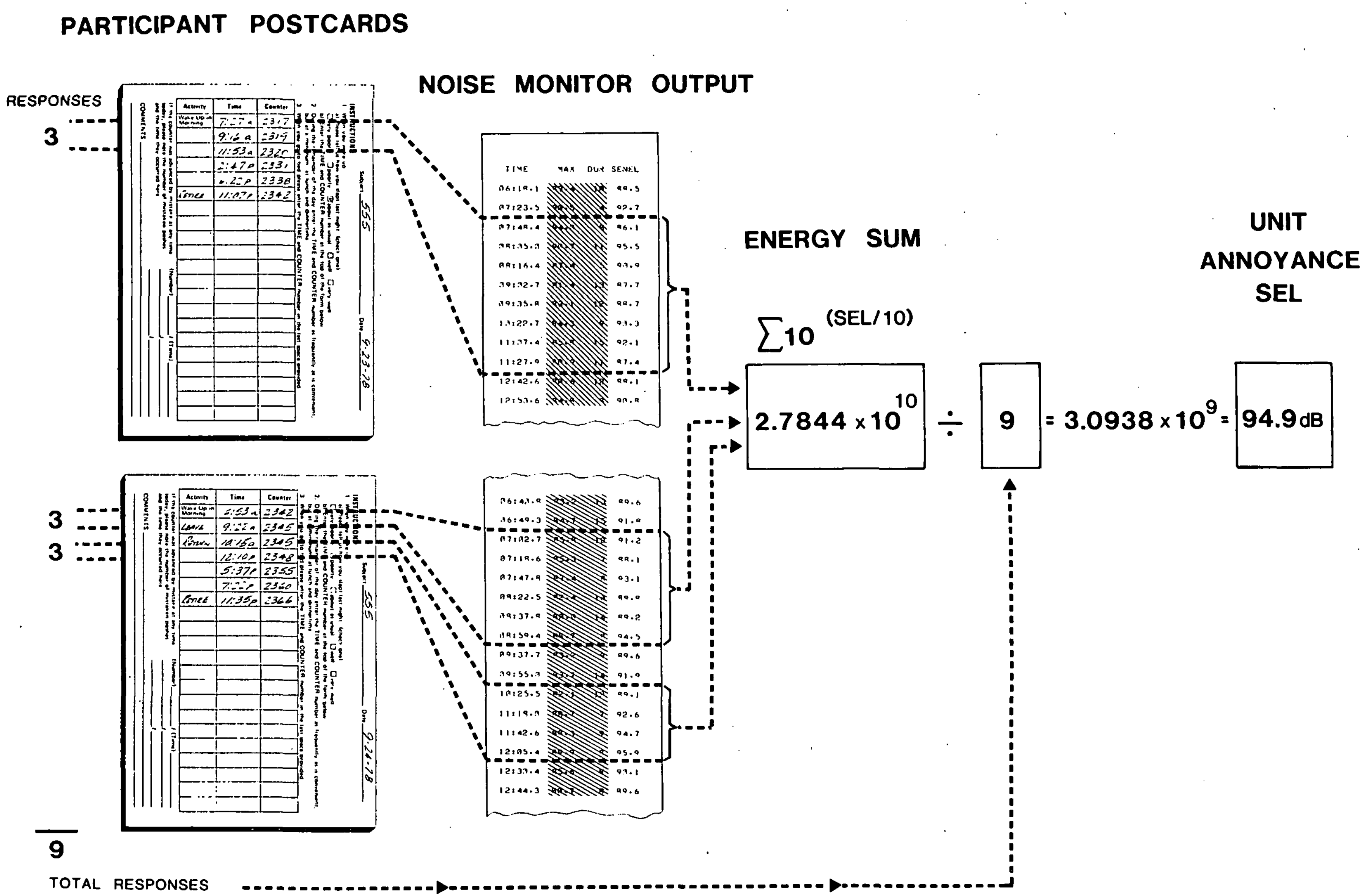


FIGURE 6. PROCEDURE FOR ESTIMATING UNIT ANNOYANCE SEL

This figure, similar to Figure 5, matches annoyance and sound level data. Instead of forming density functions from the noise level data, the SEL's were summed on an energy basis. This sum was then divided by the number of annoyance responses to yield an equivalent SEL per response.

V. RESULTS

A. Overview

The analyses reported below suggest that people do not consistently find aircraft flyover noise more annoying at one time of day than at another time. Three methods of analysis estimated the differences in levels for the same annoyance for either evening or night compared to morning to be less than two decibels. Although some individuals did find aircraft noise exposure more aversive at some times of day, such opinions were not consistent across test participants.

B. Data Analysis

1. General Trends in Annoyance Responses

The number of times individuals indicated annoyance over the two to four week period are shown in Figure 7 for various times of day for each community. Notice that in spite of the fairly large overall range (from 13 to 2000 responses), the ranges for different times of the day do not vary appreciably. Greater numbers of responses were made in the Atlanta communities, presumably because of the increased aircraft exposure. The definitions of the various time periods are as follows:

morning - time from awakening until lunchtime
afternoon - lunchtime to dinnertime
evening - dinnertime to retiring
night - retiring to awakening in the morning

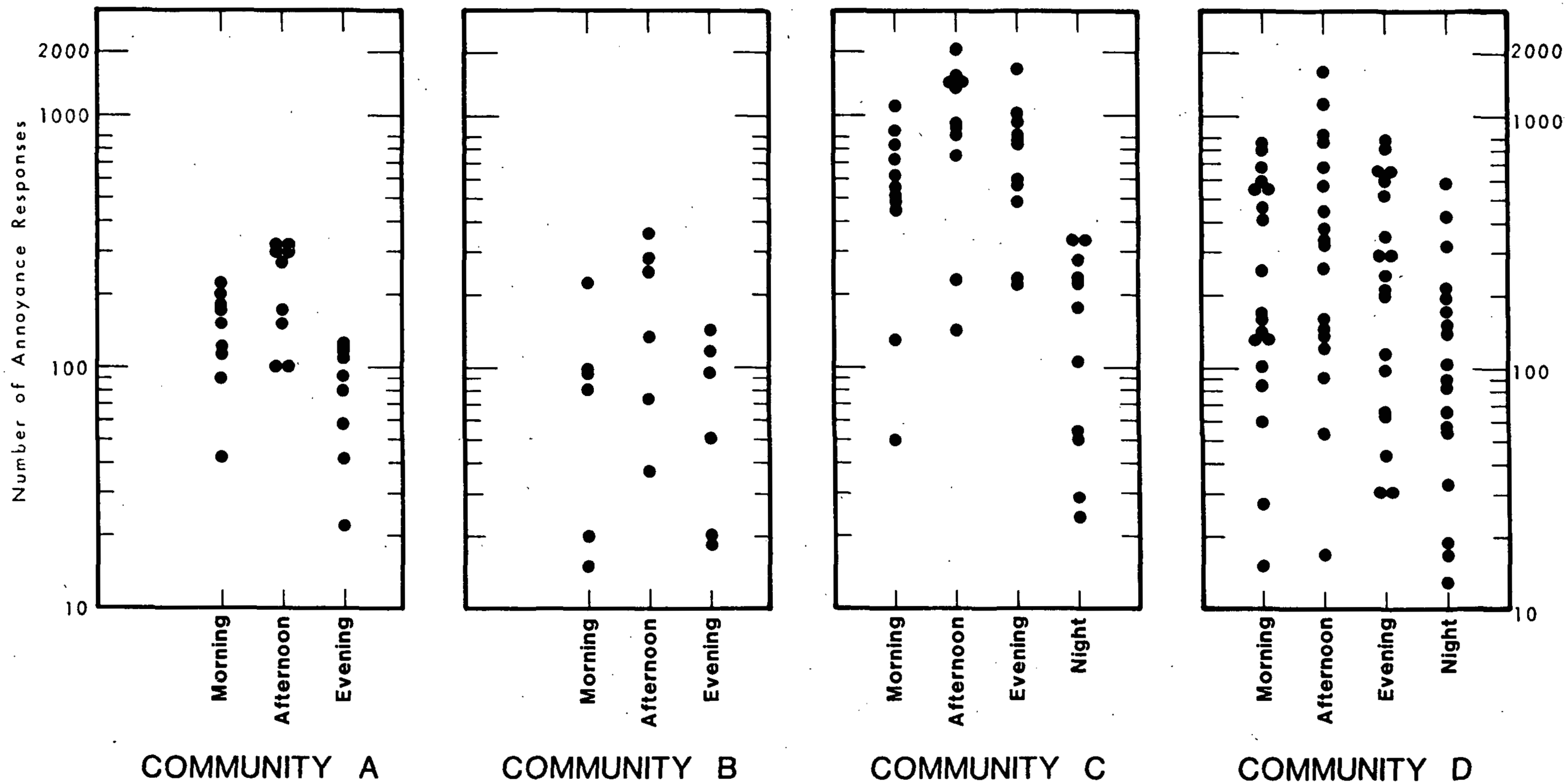


FIGURE 7. TOTAL ANNOYANCE RESPONSES FOR DIFFERENT TIME PERIODS

Since everyone does not sleep and eat at the same time, it was necessary to provide some overlapping times for the computer searches for the different time periods. These times are 0630-1230 for morning, 1130-1930 for afternoon, 1800-0100 for evening, and 2130-0730 for night.

The evening interval (1800-0100) included many annoyance reports of late retiring individuals who reported counter totals at dinnertime but not again until retiring. A narrower time window (1830-2230) was originally chosen for the evening period, but this interval significantly reduced the number of observed responses. No nighttime responses are shown for Burbank communities due to the low level of night operations. Thirty-one percent of the Burbank respondents did not register any nighttime responses. The 69 percent who did respond at night generated fewer than an average of one response per night per person over the two week period. Tabulations of all of the responses and associated levels as well as summary tables of the analysis performed in the results section are presented in Appendix D.

2. General Trends in Annoyance Responses and Sound Levels

Figures 8 through 11 show the response information depicted in Figure 7 plotted as a function of the total SEL of aircraft noise*. The points are coded for different itmes of day. In general, the

---

*The total SEL of aircraft noise is the logarithmic sum of all individual SEL's the participant was exposed to during the test period. SEL's for events were excluded for times the participant was not at home.

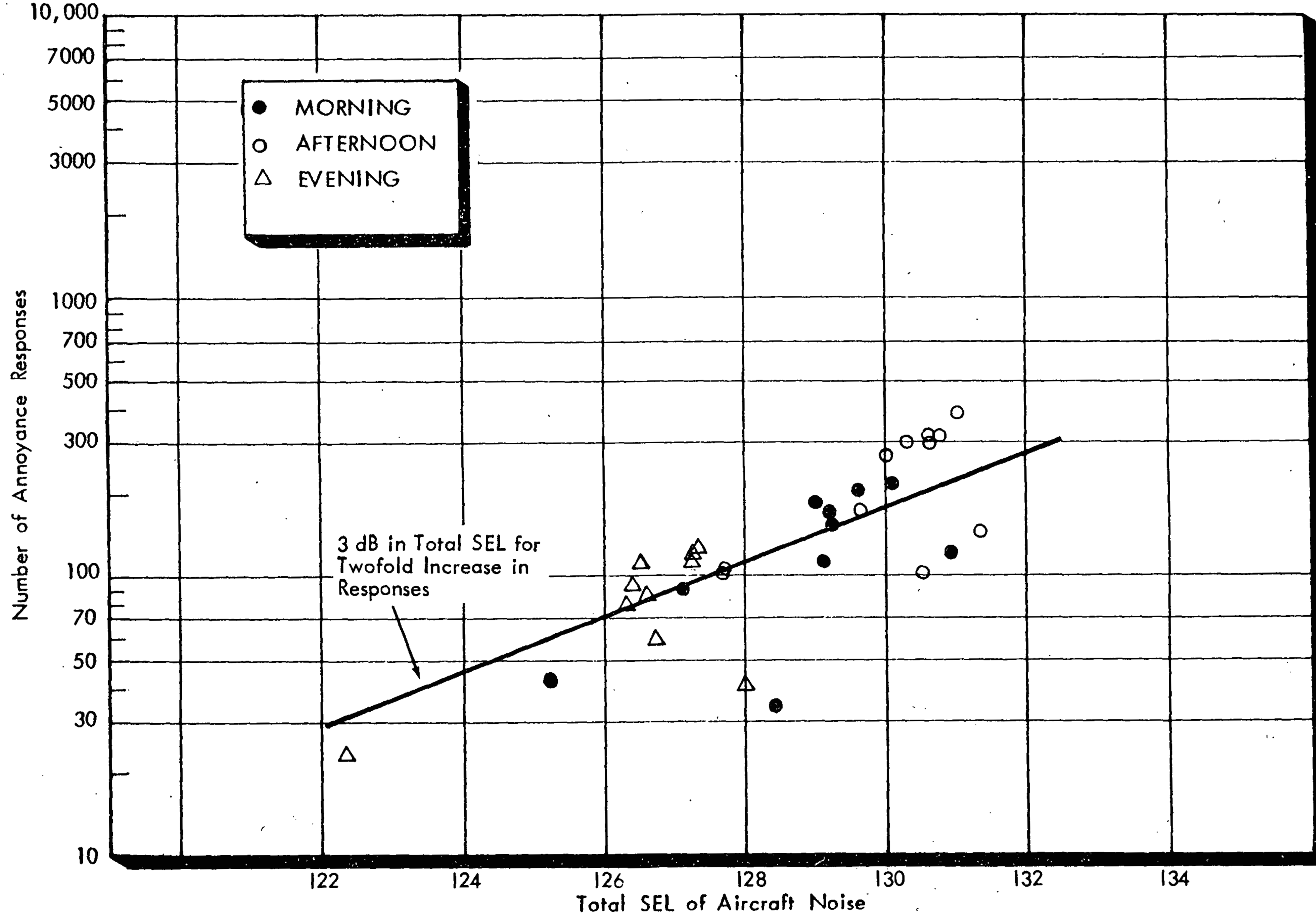


FIGURE 8. TOTAL ANNOYANCE RESPONSE FOR COMMUNITY A - BURBANK

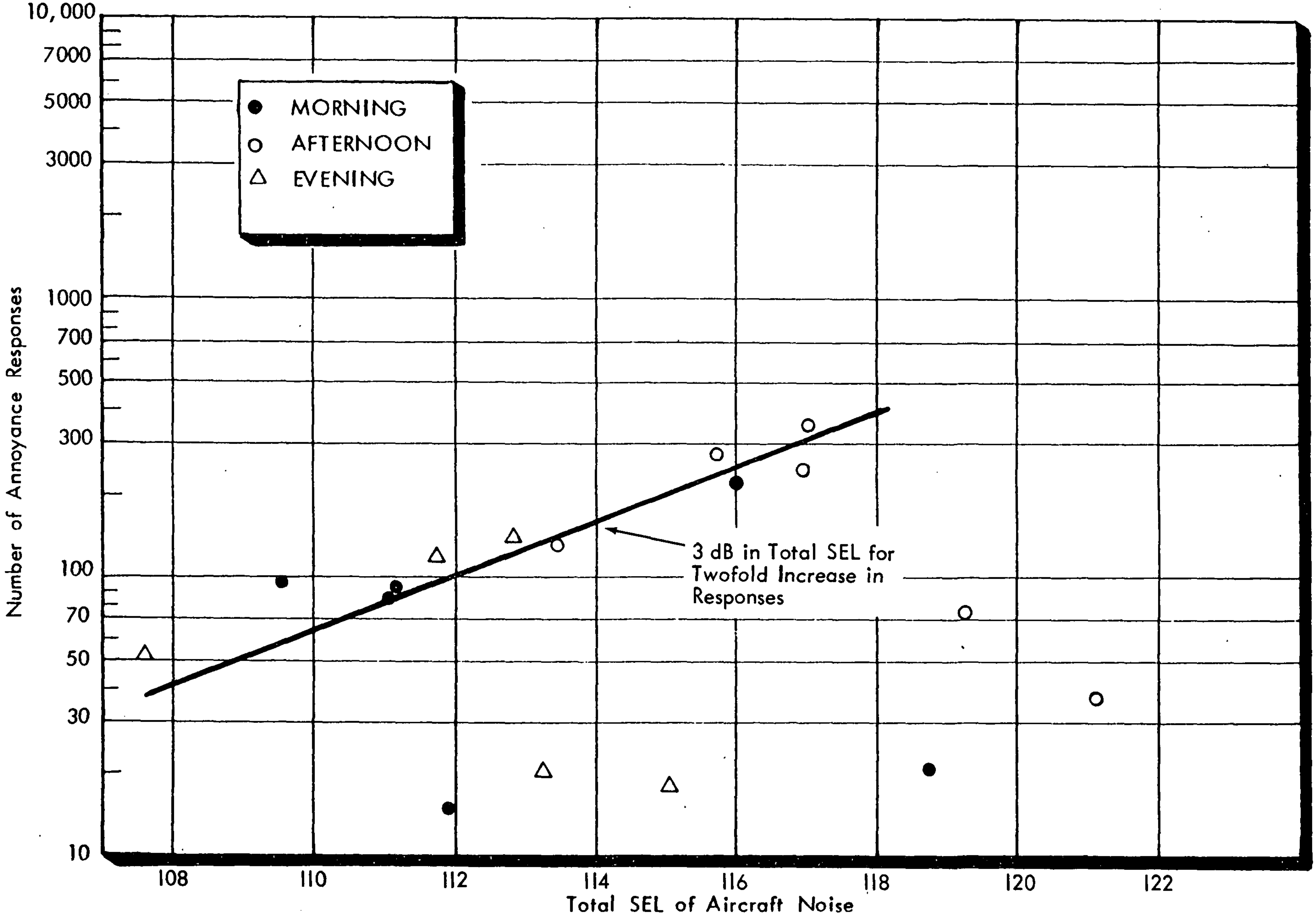


FIGURE 9. TOTAL ANNOYANCE RESPONSE FOR COMMUNITY B - BURBANK

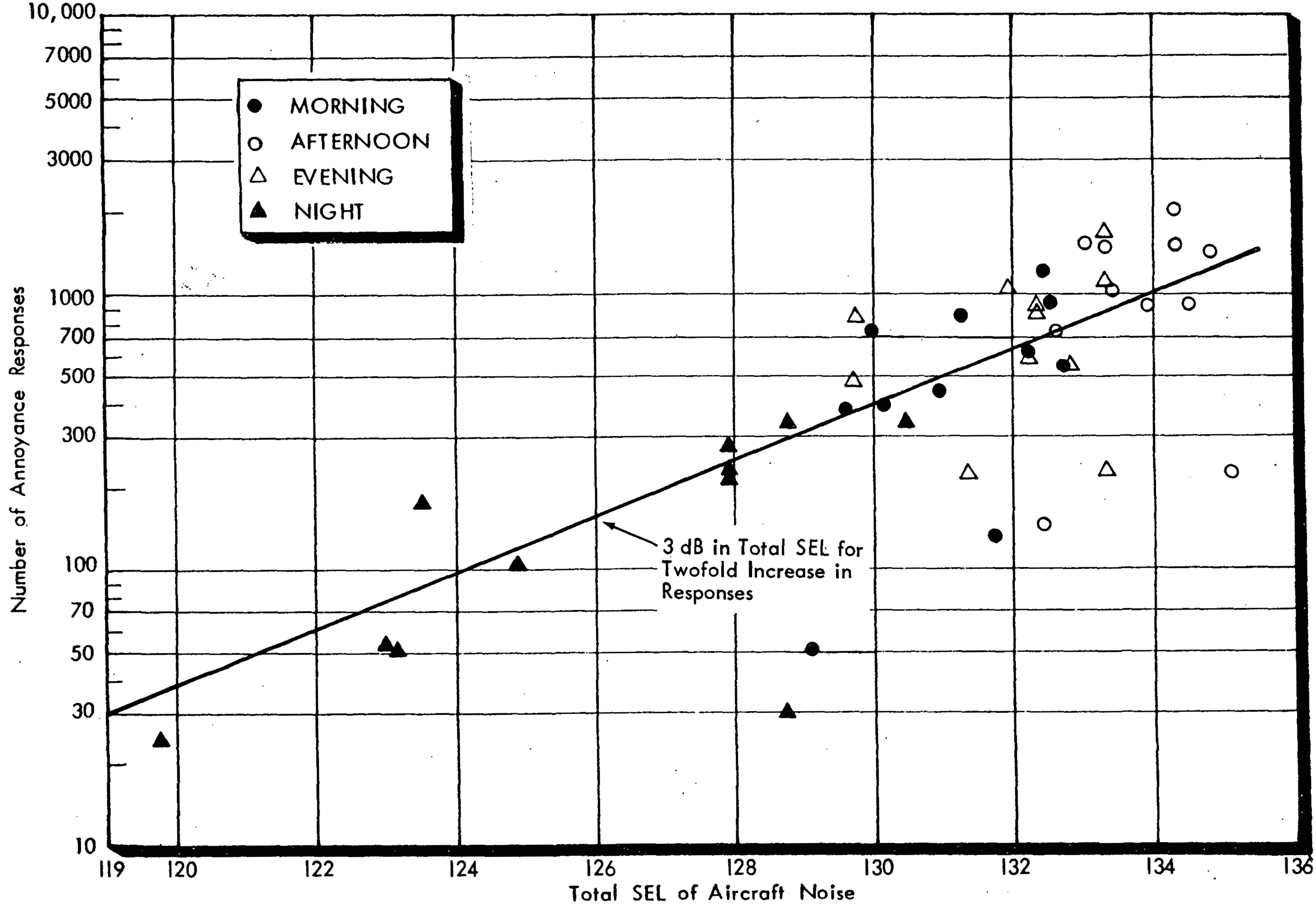


FIGURE 10. TOTAL ANNOYANCE RESPONSE FOR COMMUNITY C - ATLANTA

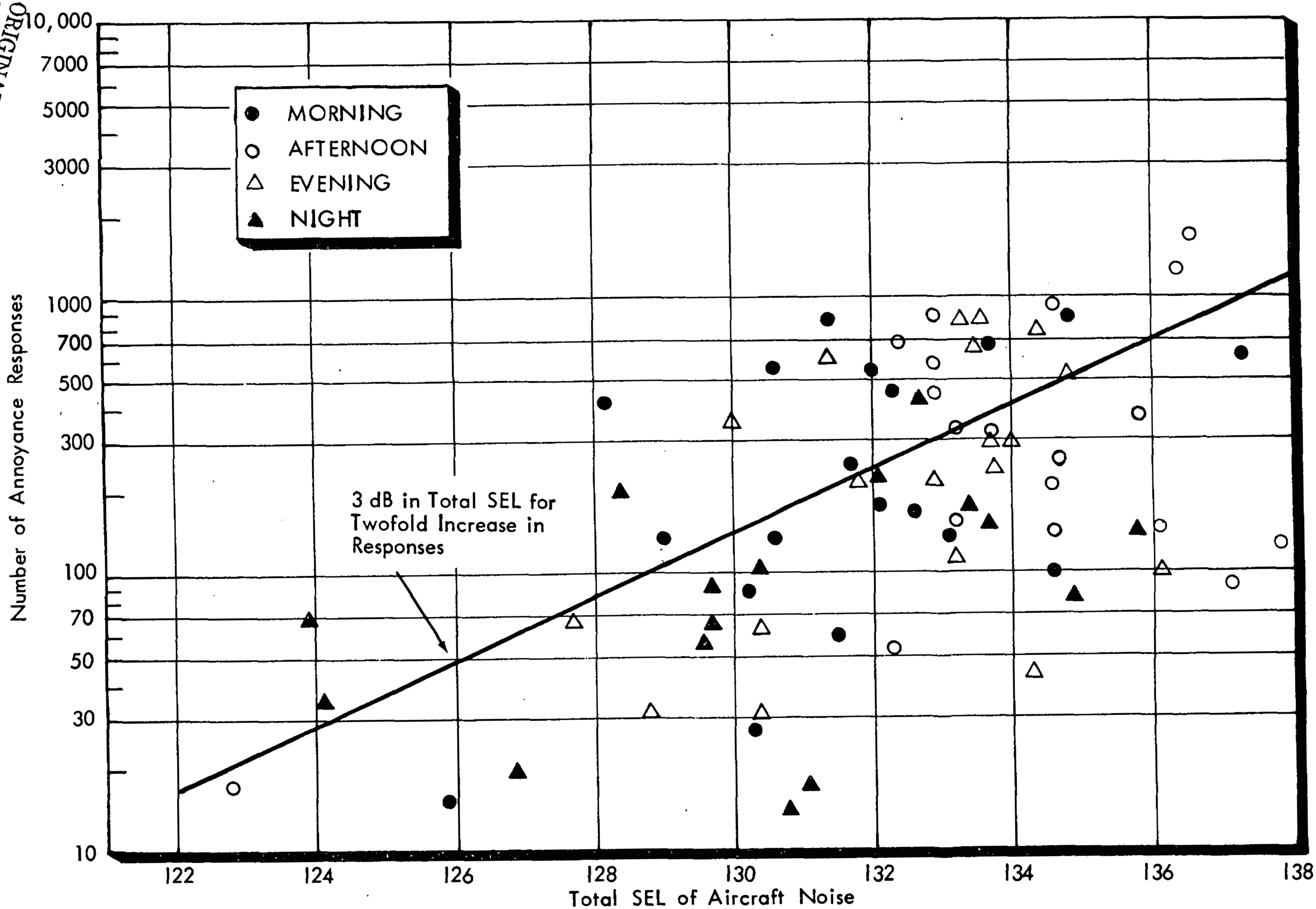


FIGURE 11. TOTAL ANNOYANCE RESPONSE FOR COMMUNITY D - ATLANTA

points fall on an "equal energy" (a doubling of responses for each 3 dB increase in total SEL) line regardless of the time of day the response was given. This suggests that there is little or no difference in the nature of the annoyance responses, whether they occur in the morning, afternoon, evening or night.

3. Differences in Annoyance Thresholds for Different Times of Day

To inspect the data more thoroughly and determine magnitudes of differences in estimated annoyance thresholds, the data were analyzed according to the procedures outlined in Section IV. Figure 12 shows the distribution of differences in estimated annoyance thresholds between morning and other periods of the day. The sound level descriptor is the maximum A-weighted sound level. A positive number means the participant felt the threshold was higher for the given time period than the morning, implying the participant was not as annoyed with the aircraft flyover noises in the given period as during the morning.

Similarly, Figure 13 shows distributions of annoyance differences using SEL as the sound level descriptor. Note that the results tend to cluster better (i.e., less inter-participant variance) using SEL as the individual event sound level metric instead of the maximum A-level.

Mean differences between night and morning were .9 dB and 1.7 dB for maximum A-level and SEL, respectively. Both differences are significantly different from zero at the 0.05 level of confidence. However, the magnitude of the difference is still small in terms of general community annoyance. Average differences in annoyance

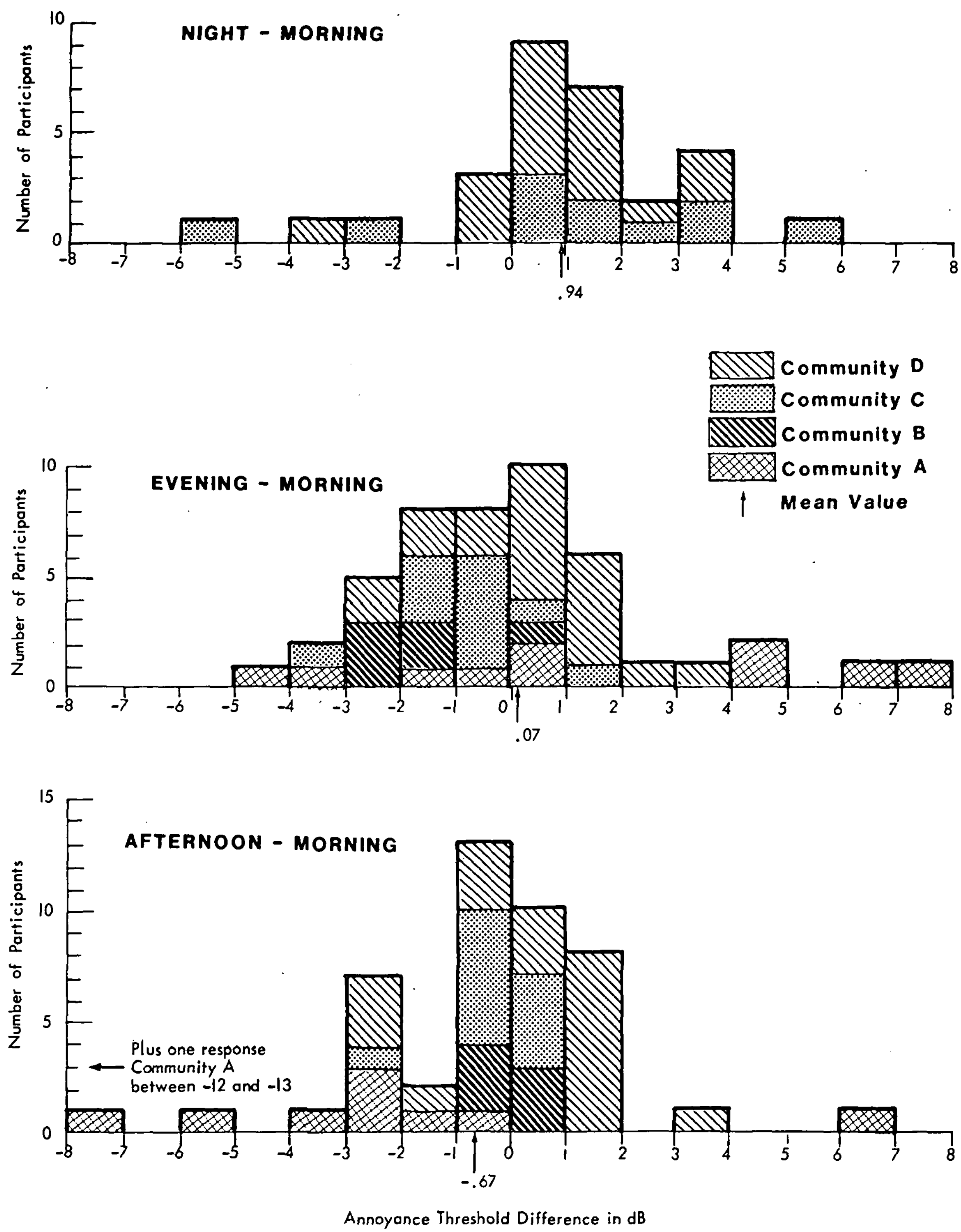


FIGURE 12. DISTRIBUTIONS OF DIFFERENCES IN ESTIMATED ANNOYANCE THRESHOLDS IN TERMS OF MAXIMUM A-WEIGHTED SOUND LEVEL

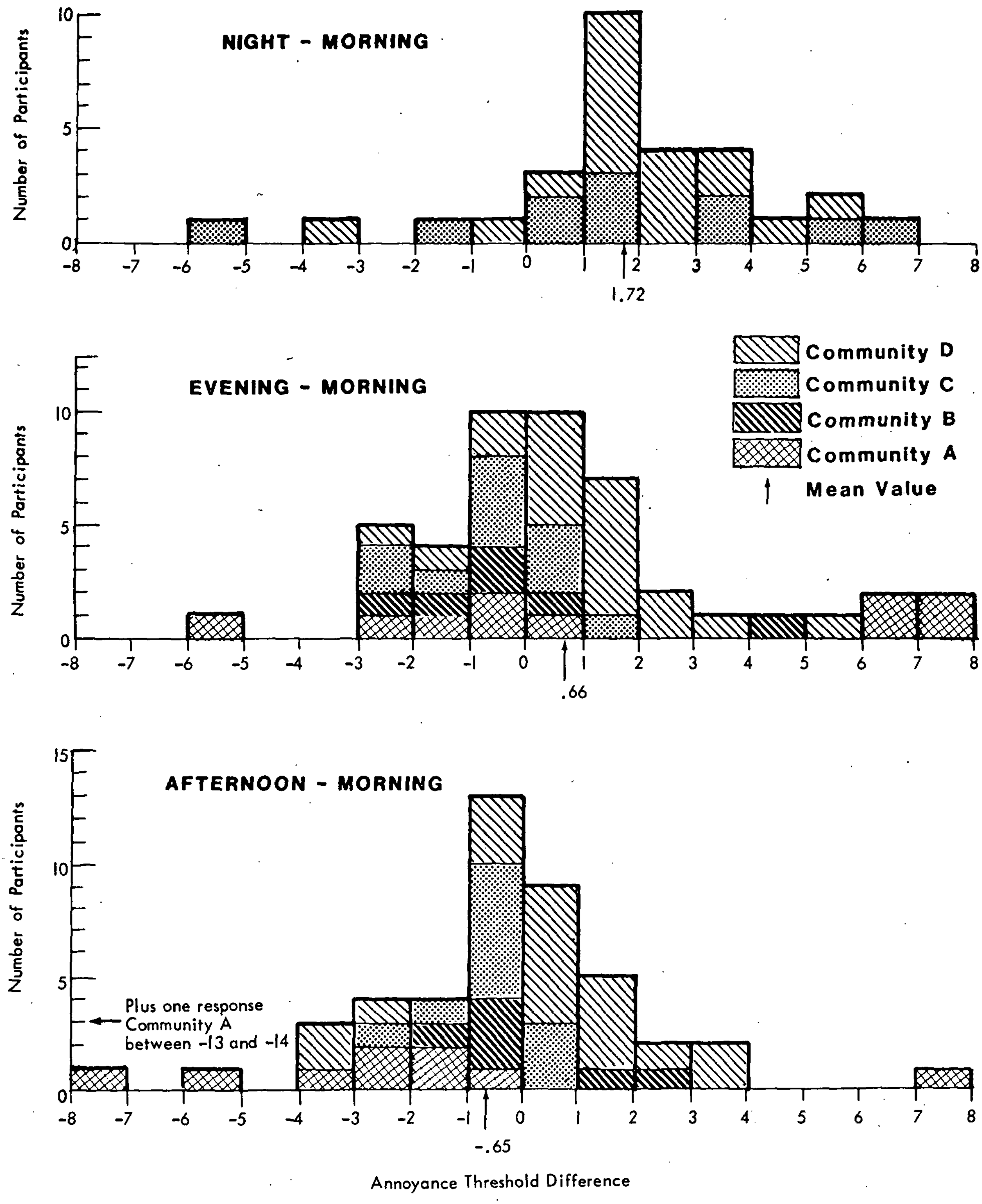


FIGURE 13. DISTRIBUTIONS OF DIFFERENCES IN ESTIMATED ANNOYANCE THRESHOLDS IN TERMS OF SOUND EXPOSURE LEVEL

between any periods of the day were always less than 1 dB for maximum A-level and less than 2 dB for SEL. Appendix E presents a complete tabulation of annoyance differences between periods of the day along with means and variances.

4. Differences in Unit Annoyance SEL for Different Times of Day

Figure 14 shows distributions similar to those shown in Figures 12 and 13, but utilizes differences in total SEL for unit annoyance (one counter response) as the parameter. The largest mean differences is 1.5 dB for the night/morning difference. This is significantly different from zero at the 0.05 level of confidence. However, once again the difference is less than 2 dB and would not have a large impact on community response. Since the difference is positive (greater level for equal annoyance), it suggests that people are more annoyed by aircraft flyovers in the morning than during the evening. These distributions, like those shown in Figures 12 and 13, further indicate that the magnitude of the difference required to attain equal annoyance for various time periods is less than the range of data collected for the various subjects.

A summary graph, Figure 15, shows the mean and standard deviations for all of the differences obtained between time periods. Note that mean differences are smaller than the standard deviation across subjects. Also, the magnitude of the mean differences, regardless of the method used to obtain the difference, is less than 2 dB. The smaller standard deviation for the analysis using the total SEL mean suggests that people's annoyance responses resemble a total energy integration more closely than individual event measures.

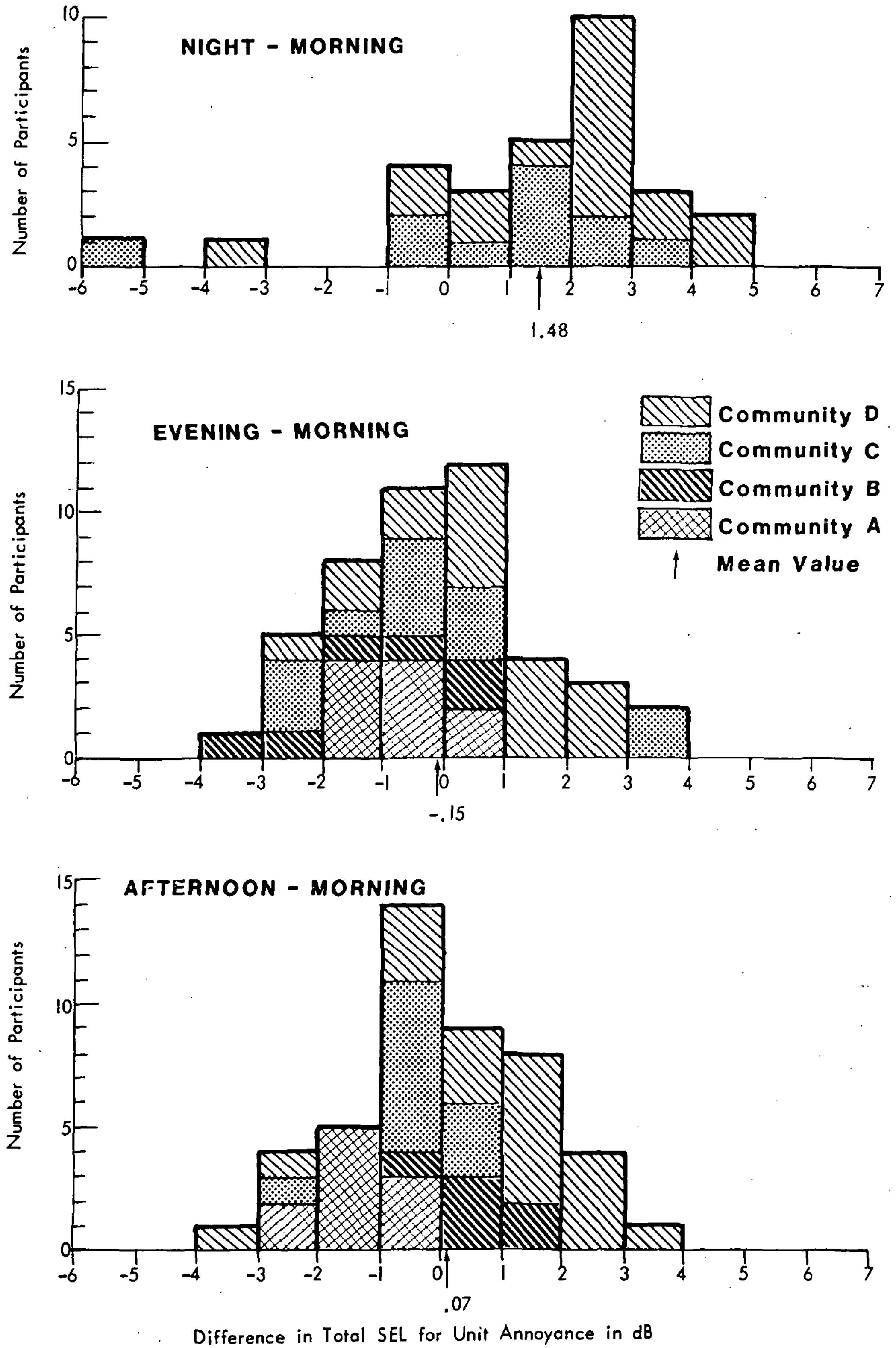


FIGURE 14. DISTRIBUTIONS OF DIFFERENCES IN UNIT ANNOYANCE SEL

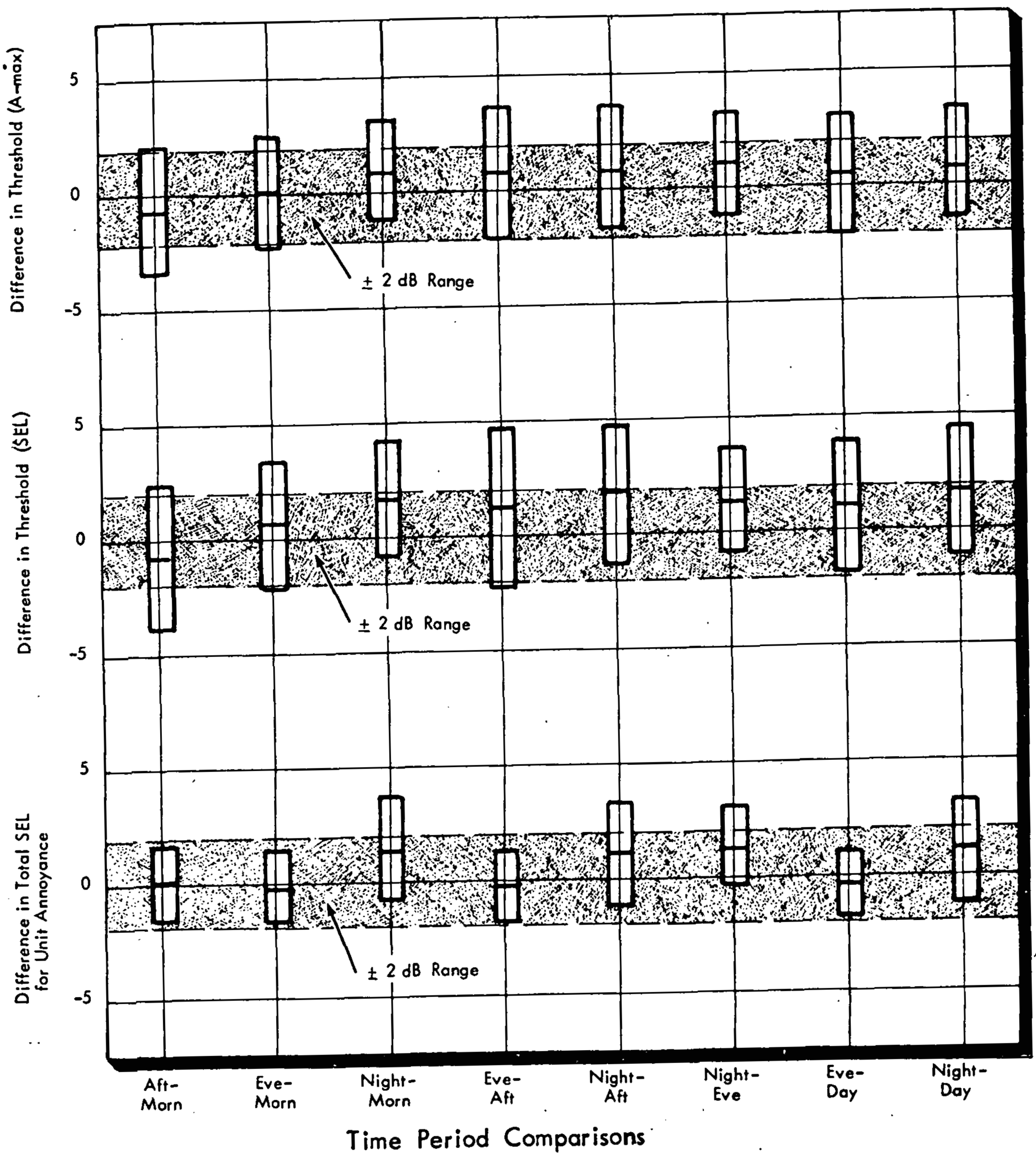


FIGURE 15. COMPARISON OF DIFFERENCES FOR EQUAL ANNOYANCE USING DIFFERENT METRICS

5. Questionnaire

Brief questionnaires were administered to participants before and after the study. These may be found in Appendix A. The major findings include the following:

1) Eighty-seven percent of the Burbank participants and 31 percent of the Atlanta participants reported they were never awakened during the study by aircraft noise at night. Further, over the two week study period in Burbank, all of the participants awoke from aircraft noise less than three times. Fifty percent of the Atlanta participants were awakened fewer than three times during the four week study period.

2) Little change in overall annoyance with aircraft noise was noted before or during the period of participation. Seventy percent of the Burbank residents in Community A indicated that they were highly annoyed by aircraft noise for the year before participation in the study, and 60 percent responded that they were highly annoyed after participation. All of the participants in Community B indicated that they were highly annoyed both before and after the study. Similarly, 89 percent of Atlanta's (Community C) participants were highly annoyed before the test and 100 percent were annoyed after the participation. Ninety-four percent of the participants in Community D were highly annoyed by aircraft noise both before and after the study.

3) Test participants found it difficult to estimate the number of button pushes they would have used for various periods of time during the day if they could have pushed them as often as they desired. In fact, many respondents stated that the flyovers were

equally annoying regardless of the time of day they occurred. However, averages were determined because of the possible relevance that this particular question had on the annoyance assessment of aircraft flyovers during different parts of the day. Responses of test participants were analyzed by first normalizing each individuals responses to a single push button during the morning hours. These normalized figures were then converted to a decibel-like number using the formula shown in Table I. The results were then averaged and are presented in Table I for various time periods. A high number for a particular time period indicates that aircraft flyovers were more annoying during that time period.

End results support the main findings of this study: there were small differences (less than 2 dB) between afternoon and evening relative to the morning responses for both the Burbank and Atlanta data. The same is true of the results for the nighttime data gathered in Atlanta.

4) Ninety-three percent of the Burbank test participants and 96 percent of the Atlanta test participants felt that the aircraft noise exposure during the study period was typical of exposure over the entire year.

TABLE I

EQUIVALENT DECIBEL DIFFERENCES FOR VALUES
REPORTED IN QUESTION 8

How often would you push the button for each flyover during - Morning? Afternoon? Evening? Night?

		TIME PERIOD		
LOCATION	QUANTITY	AFTERNOON	EVENING	NIGHT
Burbank	Mean	-0.9*	1.6	
Burbank	Standard Deviation	3.9	4.7	
Atlanta	Mean	-0.5	1.4	0.3
Atlanta	Standard Deviation	3.4	3.8	3.1

* $10 \log \left[\frac{\text{Button Push (Time Period)}}{\text{Button Push Morning}}\right]$

VI. DISCUSSION

A. Major Findings

Useful information was obtained from the study conducted at the two airports. In general people were willing to provide annoyance responses by "pushing the button when they would rather not have heard an aircraft flyover" for a period of two to four weeks. The overall method was satisfactory in determining gross measures of annoyance for the time periods under evaluation. However, a more refined scheme with automatic time recording and annoyance magnitudes is necessary to measure more subtle changes in annoyance patterns for various time periods. It is clear, however, that no appreciable (greater than 2 dB) differences in annoyance were observed between the average of the time periods examined in the current study.

B. Possible Sources of Error

The unexpected results of the study led to a closer examination of the assumptions underlying the three models used to analyze the annoyance and noise data and data collection techniques. The following discussion considers possible sources of error.

1. Subject Selection

Participants were chosen through door-to-door canvassing of areas falling within certain noise boundaries. It is unlikely that people who agreed to participate in the study were biased in their annoyance responses since they had no knowledge of the exact purpose of this study other than their task: to rate noise from aircraft flyovers.

It is true that only those people who were at home most of the day were selected as test participants. This selection process was dictated by the nature of the analysis procedure which required noting differences in annoyance for the different time periods. Clearly, if one was not home during the morning or afternoon, the annoyance of the aircraft flyovers during those periods could not be determined and consequently, no difference could be noted between morning or afternoon and other time periods. However, the fact that all people are not at home during the day is an extremely important factor in the eventual determination of a nighttime or evening penalty.

Consider the example of a community in which only one-third of the population is home during the day, but close to 100 percent of the population is home during the evening hours. Assume that 25 percent of the people are highly annoyed by aircraft noise when they are exposed to it. Thus, at night, when most of the community residents are at home, 25 percent of the total population are highly annoyed by aircraft noise. However, during the day, when only one-third of the population is at home, an annoyance response of 25 percent is equivalent to only 8 percent of the entire population. Thus, three times as many people are annoyed by aircraft noise in the evening as were annoyed during the day. This might be converted to a 5 dB increase in annoyance during the evening hours since the greater proportion of the people are home during those hours. This consideration was not addressed by this study.

2. Possible Error of Physical Measurement

a) The measurement system used to collect the aircraft noise data was also examined as a possible source of error. It is certainly true that not all of the aircraft flyovers in each community were measured. The noise level of many flyovers heard by people fell below the threshold setting of the noise monitor units. However, the relative difference in annoyance caused by aircraft noise at different time periods was the variable of interest. Approximately the same percentage of aircraft fell below the threshold value of the noise monitor during the morning/daytime period as during the evening and nighttime hours since the distribution of sound levels from single events remained virtually constant over the entire day (see Appendix C). No bias can be attributed to aircraft whose levels were less than the threshold setting as long as the number of responses indicated by each participant was less than the total number of aircraft measured during that time period.

b) Another type of measurement error considered was the recording of a sound other than an aircraft flyover when the threshold of the noise monitor was exceeded. Such events would essentially be counted as an aircraft flyover event. However, since the monitor operated over the twenty-four hour period, there is no reason to expect a particularly large number of false alarms in one time period over another. In order to have any significant effect, the number of false alarms would have to be double the total number of events for the analysis using the total SEL necessary for one push button. There would have to be a 20 percent increase in false alarms for the corresponding threshold analyses. Even given both of these circumstances, the results would produce only a 3 dB change in annoyance. This number of false alarms would be highly unlikely; daily visits to the sites (or visits every other day in the Burbank communities) would also have detected problems of this nature.

3. Credibility of Subjective Measurement

a) Some response data could not be used because of differences in times that counter totals were recorded. Pairs of sequential counter reports could not be used if they did not fall within a time period. About 20 percent of the data was omitted for the morning, afternoon and evening periods in both Burbank and Atlanta because of this reason. However, about one-third of the night responses could not be used in Atlanta, due primarily to late morning wakeups. More response data could have been included if the night period was extended beyond 7:30 in the morning. However, there was concern that extending the night period until a later morning hour would include annoyance responses recorded after people woke up. (This would include people who tabulated their counter totals both upon wakeup and after breakfast.) Therefore, the nighttime period ended at 7:30 a.m. for the computer analysis.

b) Similar tradeoffs were made in the selection of boundaries for the other time periods. Since the unusable data was uniform across the morning, afternoon and evening time periods, it was felt that no bias would exist from losing this data. Also, restricting the time periods as narrowly as possible provided more meaningful results. The loss of data because of the boundaries of the time periods further illustrates the need for a self-contained response mechanism to record the actual time of response. This would allow investigation of time periods broken down in many ways rather than limiting the periods to the ones tested in this study.

c) Test participants pushed the counter button hundreds of times during each time period throughout the study. Thus the thresholds estimated for each individual for the four time periods were based on a large number of annoyance responses. Figure 16 shows the cumulative distribution of aircraft noise heard by Subject 225 in Community D during the morning hours for four weeks. All noise caused by aircraft flying over Community D while Subject 225 was away from her home was omitted from the distribution function (as indicated on her daily postcard entries). Subject 225 pushed the counter button a total of 874 times during the twenty-eight mornings, as indicated by the arrow labelled "annoyance responses". The corresponding maximum A-level threshold was estimated to be 94 dB(A). Note that to obtain a 3 dB decrease in estimated maximum A-level threshold, Subject 225 would have to have registered over two hundred additional annoyance responses. Though each participant pushed the counter according to his own internal threshold, comparable numbers of annoyance responses were registered by participants during the time periods, providing very stable threshold estimates.

4. Questionnaire

The results of the brief post-study questionnaire data were in agreement with the main part of the study. That is, neither the

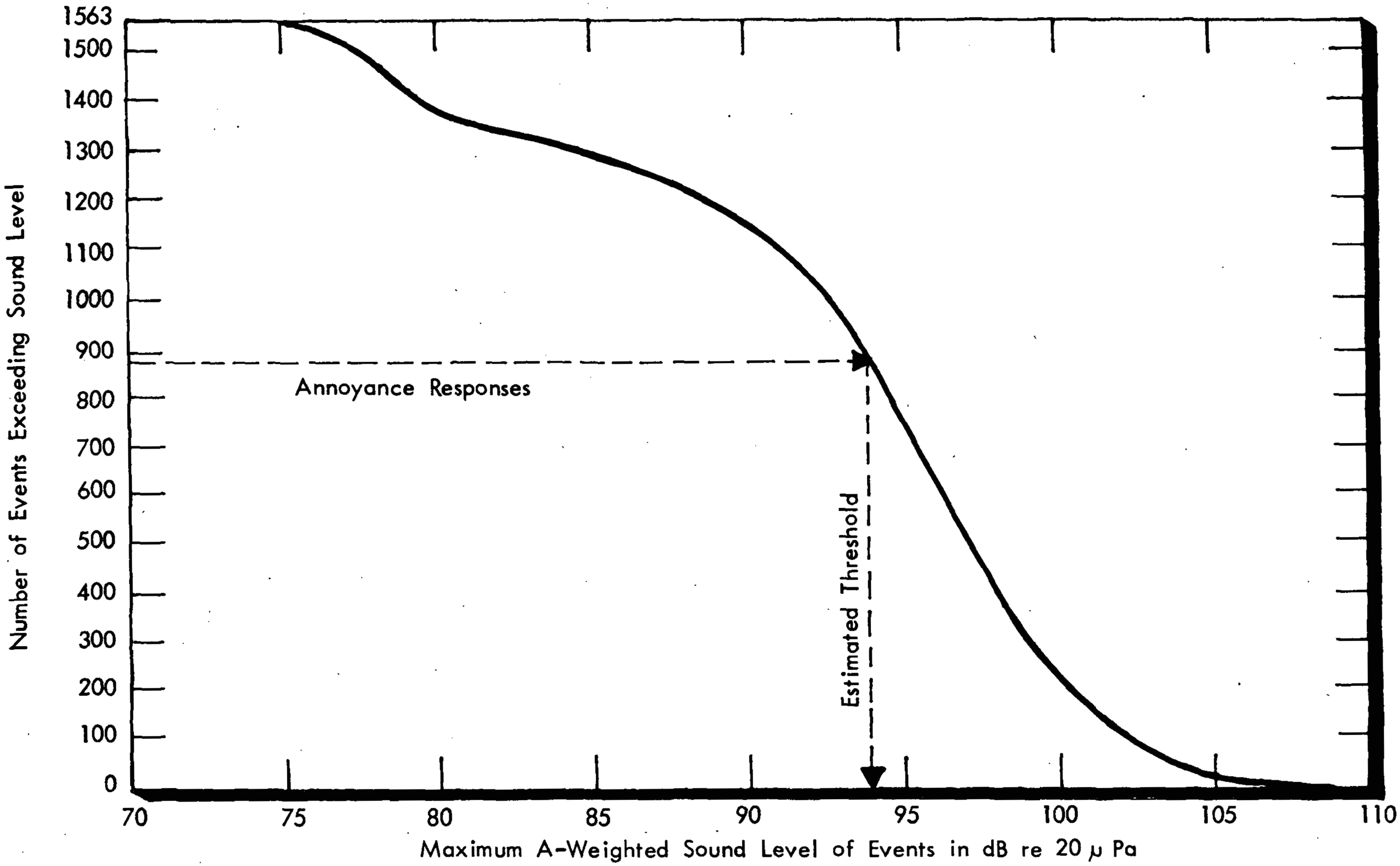


FIGURE 16. SAMPLE CUMULATIVE DISTRIBUTION FUNCTION FOR ESTIMATING ANNOYANCE THRESHOLD (Subject 225 Morning)

questionnaire results nor results from the main study suggest a great difference between annoyance determined for various time periods in the day. To be sure, the results of the questionnaire response indicated that some individuals were much more annoyed by aircraft flyover noise during the evening hours than during the morning hours. However, other individuals were very annoyed by flyovers occurring during the morning hours, and not as much by those occurring during the evening hours. This explains why the average of all of the results indicates little (less than 2 dB) difference between annoyances for the various time periods under consideration.

5. Relationship to Prior Findings

The percent of people highly annoyed by aircraft noise in the four communities is quite high compared to results of other researchers (Schultz, 1978). However, a partial explanation for the higher percentages noted in this study lies in the special nature of the test participants.

Most of the participants were very annoyed by the aircraft noise in their communities and thus were willing to perform the required task for the study. However, in the Burbank area, approximately one out of four people contacted agreed to take part in the study. The other 75 percent of the people stated that aircraft noise did not annoy them. In Atlanta, almost two out of three people agreed to take part in the study. Figure 17 shows percent highly annoyed to aircraft noise in the four communities when the entire group of people that were asked to participate in the study are included. The adjusted estimates of percent highly annoyed agree reasonably well with prior research (Schultz, 1978).

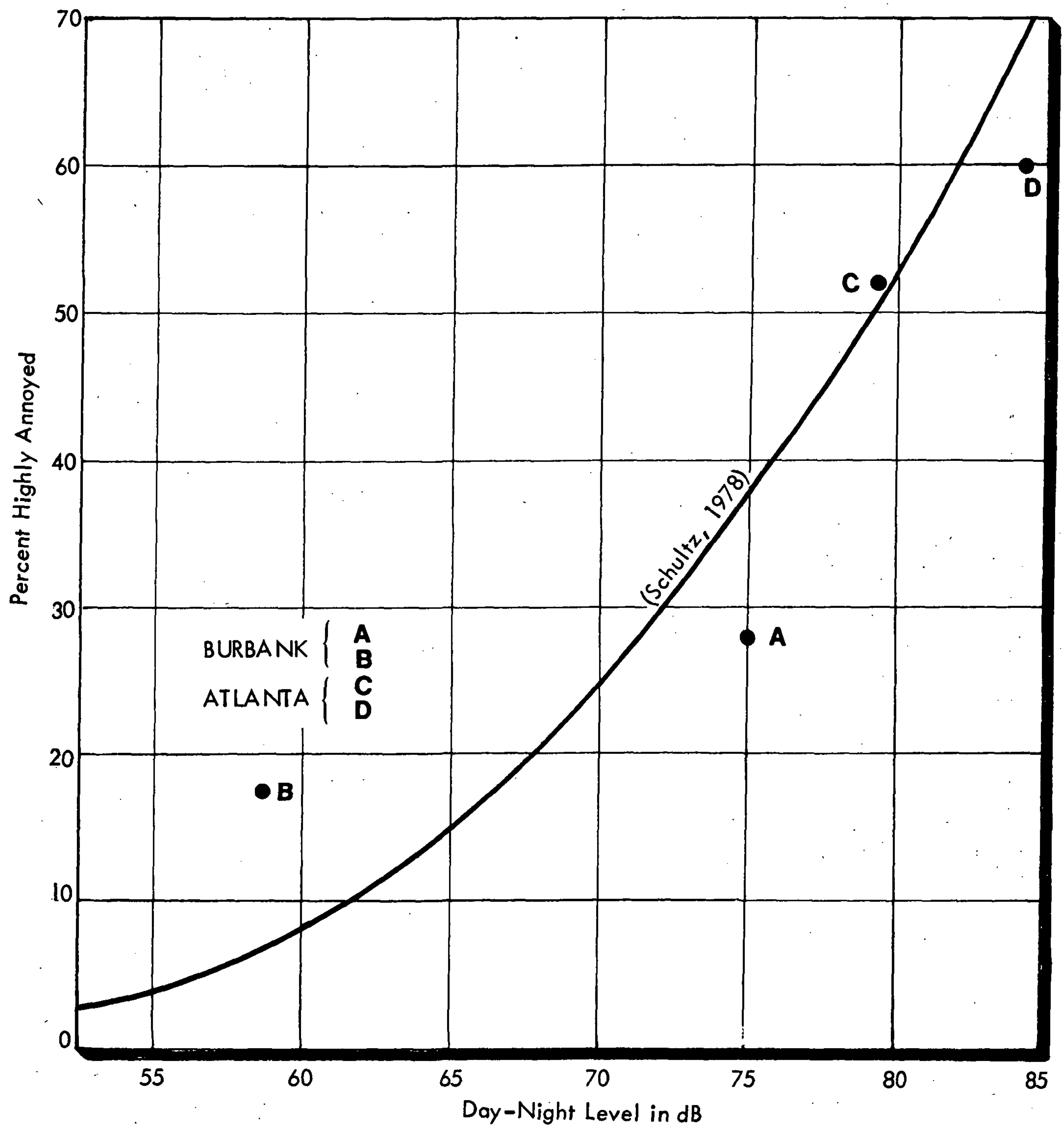


FIGURE 17. PERCENT OF PEOPLE HIGHLY ANNOYED BY AIRCRAFT NOISE IN BURBANK AND ATLANTA COMMUNITIES (INCLUDES ALL PEOPLE ASKED TO PARTICIPATE IN STUDY

VII. CONCLUSIONS

1) Assessment of annoyance due to aircraft noise exposure can be accomplished by immediate measurement of annoyance produced by individual aircraft noise intrusions in real time. People performing such a task for weeks at a time respond in an internally consistent manner, even though different people disagree on absolute levels of flyover noise considered to be annoying.

2) Three different analyses of over 1200 person-days of data produced by the current technique in two airport communities revealed no major differences in the annoyance of aircraft noise exposure as a function of time of day. Differences between morning and afternoon periods were statistically insignificant. Differences between evening and nighttime periods and other times of day (morning, afternoon, and combined daytime hours), although unlikely to have arisen by chance alone, were small (less than two decibels) and of little practical significance.

3) The observed differences in annoyance at different times of day do not in themselves support the current 10 dB nighttime penalty for aircraft noise exposure. Indeed, these small differences in sensitivity would suggest a slightly greater tolerance for nighttime noise exposure.

4) The absence of direct evidence of differential annoyance at varying times of day does not resolve the controversy over the appropriateness and magnitude of time of day weighting factors for cumulative measures of community reaction to noise exposure, since this controversy also concerns issues having little to do with scientific evidence of human reactions to noise exposure.

5) Conduct of more definitive studies of time of day weighting factors by the current technique requires development of a micro-processor based apparatus for recording the time of occurrence and degree of annoyance attributable to individual aircraft flyovers.

REFERENCES

Fidell, S., G. Jones and K. Pearsons, "Feasibility of a Novel Technique for Assessing Noise-Induced Annoyance", Department of Transportation Report DOT-TST-74-3, September 1973, NTIS PB-225334.

Fidell, S., and G. Jones, "Effects of Cessation of Late-Night Flights on an Airport Community", J. Sound and Vibration, Vol. 42, No. 3, October 1975. See also "Reply to Patterson's Comments", J. Sound and Vibration, Vol. 47, No. 3, August 1976.

Galloway, William J., "Nighttime Adjustment in the Rating of Community Noise Exposure", NASA Contract No. NAS1-14611, September, 1977.

Horonjeff, Richard D., Ricarda L. Bennett and Sherri R. Teffeteller, "Initial Study on the Effects of Transformer and Transmission Line Noise on People: Sleep Interference", Vol. 2, BBN Report 3710, December 1978.

Ollerhead, J. B., "Variation of Community Response to Aircraft Noise with Time of Day", Noise Control Engineering, 11(2), 68-78, September-October 1978.

Purcell, A. and R. Thorne, "An Alternative Method for Assessing the Psychological Effects of Noise in the Field", J. Sound and Vibration, Vol. 55, No. 4, December 1977, pp. 533-544.

Rosenblith, Walter A., Kenneth N. Stevens and BBN Staff, "Handbook of Acoustic Noise Control: Volume II, Noise and Man", WADC Technical Report 52-204, June 1953, Wright Air Development Center, Ohio.

Schultz, Theodore J., "Synthesis of Social Surveys on Noise Annoyance", J. Acoust. Soc. Am., Vol. 64, No. 2, August 1978.

Stevens, K., W. Rosenblith and R. Bolt, "A Community's Reaction to Noise: Can It be Forecast?", Noise Control, 1, 1955, pp. 63-71.

APPENDIX A

TEST INSTRUCTIONS, SAMPLE POSTCARDS, AND SAMPLE QUESTIONNAIRES

Appendix A includes a copy of the detailed test instructions given to participants in the Atlanta, Georgia area. Test instructions given to participants in Burbank differ only by the sample postcard included in the instructions. Figures A-1 and A-2 show copies of the postcards used by participants in the two areas. Pre- and post-study questionnaires are also included in the Appendix.

Los Angeles Office
21120 Vanowen Street
Post Office Box 633
Canoga Park, CA 91305
Telephone (213) 347-8360

Bolt Beranek and Newman Inc.
Consulting Development Research

ABOUT THIS STUDY

The National Aeronautics and Space Administration (NASA) would like information about how people react to aircraft noise on a day-to-day basis in their own homes. This is not the first scientific study of opinions about aircraft noise, but most previous studies have used a questionnaire to assess people's reactions to aircraft noise. Questionnaires often ask questions like "How many times a day are you bothered by aircraft noise?" to gauge peoples reactions. Questions of this sort may be hard for people to answer, since reactions to aircraft noise may change from day to day or from hour to hour. This study provides people with an opportunity to directly register their opinions about aircraft noise at the very moment it occurs.

Boston Washington Los Angeles

HOW TO USE THE COUNTER

The counter is your way to indicate annoyance with an aircraft flyover. Your instructions are:

> PRESS THE COUNTER ONCE (AND ONLY ONCE) EACH TIME YOU HEAR AN AIRCRAFT FLYOVER YOU WOULD RATHER NOT HAVE HEARD AT THAT MOMENT

We are interested in only <u>your</u> opinion about aircraft noise, not how you think your family or friends would feel. However, your job is <u>not</u> to count each airplane you can hear regardless of how loud or how faint it is. Noise measuring equipment is doing that. <u>Your</u> job is to provide the all important human interpretation and to count only those aircraft which are annoying at the moment you hear them. We know that many factors contribute to a person's annoyance, and that you may push the counter more often some days than others. All we care about however, are your immediate feelings whenever you hear aircraft noise.

This is a 24 hour study, so we want you to continue to record your reactions to aircraft noise even during times when you are normally asleep. In short, we want you to take your counter to bed with you (you can put it under your pillow or some other easy to reach place). We don't expect you to press the counter in your sleep, but if you should hear an aircraft flyover you would rather not have heard while in bed, we want you to press the counter. Furthermore, if you should wake up for any reason press the counter once.

HOW TO USE THE POSTCARDS

Fill out one postcard every day.

WHEN YOU FIRST WAKE UP IN THE MORNING start a new card by (1) filling in the date and (2) checking the box which most closely describes how you slept the previous night. Then, fill in the time (from the wristwatch we provided) and your counter reading in the two boxes next to "Wake Up in Morning".

DURING THE DAY AND EVENING we need to know how your opinions vary from time to time. As often as you find convenient, please write down your current activity, the time (from the wristwatch), and the number showing on the counter. At the very least we need this information twice during the day, once at noon (just before lunch) and again around 6 pm (just before dinner).

IF YOU LEAVE YOUR HOME for any reason (such as for shopping, to visit a friend, etc.) we need to know when when you left and when you returned. When you leave please write the word LEAVE under "Activity", the time (from the wristwatch), and the number showing on the counter. When you return write the word RETURN under "Activity", the time, and the number on the counter.

WHEN YOU RETIRE FOR THE EVENING Write the word RETIRE under "Activity", the time, and the number showing on the counter. Don't forget to take the counter to bed with you!

IF THE COUNTER IS PUSHED BY MISTAKE at any time, just write down the number of times you believe the button was mistakenly pressed and the time it occurred next to "(Number)" and "(Time)" in the lower right hand corner of the card.

HOW TO USE THE POSTCARDS (continued)

A SAMPLE CARD, correctly filled out, is shown below. "####" in the "Counter" column is supposed to mean the numbers showing on your counter.

Subject 246 Date 2/25/79

INSTRUCTIONS:

1. When you wake up:
   a) Please tell us how you slept last night (check one)
   ☐ very poorly ☐ poorly ☐ about as usual ☐ well ☐ very well
   b) Enter the TIME and COUNTER number at the top of the form below.
2. During the remainder of the day enter the TIME and COUNTER number as frequently as is convenient, but at a minimum at lunch and dinnertime.
3. When you go to bed please enter the TIME and COUNTER number in the last space provided.

Counter	####	####	####	####	####	####	####	####	####
Time	6:23am	9:45am	10:22am	11:07am	12:36pm	3:17pm	6:28pm	9:13pm	11:22pm
Activity	Wake Up in Morning	House work	Leave	Arrive	Lunch	Reading	Dinner	TV	Retire

If the counter was advanced by mistake at any time today, please note the number of mistaken pushes and the time they occurred here:

(Number) 2 / (Time) 4:17 pm
1 / 7:09 pm
/

COMMENTS:

WHEN YOU RUN OUT OF POSTCARDS ...

When you have completed your last postcard (there are 28 of them) the study is over. Please put the counter and belt in the small, stamped envelope (it's a tight squeeze, but it will all fit) and staple the envelope shut (tape will do but 4 staples are much better). Do not put the wristwatch in the envelope, the watch is yours to keep as a token of our appreciation for your help. Once again, THANK YOU!

SHOULD YOU HAVE FURTHER QUESTIONS ABOUT THIS STUDY ...

If you would like further information about this study please call us collect at 213 / 347-8360. When the operator at Bolt Beranek & Newman answers, just tell her you are calling from Atlanta about the noise study and that you would like to speak with Mr. Richard Horonjeff.

Subject No.: ______________ Date ______________

INSTRUCTIONS:

Please press the counter button once each time you hear aircraft noise that you would rather not have heard. Write the time of day and the counter total on the hour in the space provided. The actual time must be the hour and minute shown by the wristwatch given to you.

MORNING		
Hour	Actual Time	Counter Total
6 am		
7 am		
8 am		
9 am		
10 am		
11 am		

AFTERNOON		
Hour	Actual Time	Counter Total
12 pm		
1 pm		
2 pm		
3 pm		
4 pm		
5 pm		

EVENING		
Hour	Actual Time	Counter Total
6 pm		
7 pm		
8 pm		
9 pm		

NIGHT		
Hour	Actual Time	Counter Total
10 pm		
11 pm		
12 am		
1 am		
2 am		
3 am		
4 am		
5 am		

Please call Ms. Ricarda Bennett (213) 347-8360 if you have any questions.

If the counter was advanced by mistake at any time today, please note the number of mistaken pushes and the time they occurred here: (Number) ______ /(Time) ______
______ / ______
______ / ______

How did you sleep last night? (Check one)

very poorly ☐ poorly ☐ about as usual ☐ well ☐ very well ☐ Name ______________

Comments: ______________

ORIGINAL PAGE IS OF POOR QUALITY

Ricarda Bennett
Bolt Beranek and Newman Inc.
Post Office Box 633
Canoga Park, California 91305

NASA 09182

FIGURE A-1 RESPONDENT POSTCARD USED FOR DAILY REPORTING OF ANNOYANCE RESPONSES (BURBANK, SITES A & B)

Subject ______________________ Date ______________

INSTRUCTIONS:

1. When you wake up:
   a) Please tell us how you slept last night (check one)
   ☐ very poorly ☐ poorly ☐ about as usual ☐ well ☐ very well
   b) Enter the TIME and COUNTER number at the top of the form below.
2. During the remainder of the day enter the TIME and COUNTER number as frequently as is convenient, but at a minimum at lunch and dinnertime.
3. When you go to bed please enter the TIME and COUNTER number in the last space provided.

Counter																					
Time																					
Activity	Wake Up in Morning																				

If the counter was advanced by mistake at any time today, please note the number of mistaken pushes and the time they occurred here:

(Number) __________ / (Time) __________
__________ / __________
__________ / __________

COMMENTS: ______________________________________

____

Richard Horonjeff
Bolt Beranek and Newman Inc.
Post Office Box 633
Canoga Park, California 91305

NASA 09182

FIGURE A-2 RESPONDENT POSTCARD USED FOR DAILY REPORTING OF ANNOYANCE RESPONSES (ATLANTA, SITES C & D)

Interviewers Initials ______

PRE-STUDY QUESTIONNAIRE

Edit Key P.

______

Item	Question	Response	Code	C.C.
1	Airport Identification ______		/ / / /	1-4
	Subject: Name ______ Address ______ Phone ______			
2	Subject Identification No. ______	Number......	/ / / /	5-8
3	Subject's Sex	Female...... Male........	1 2	
4	Subject's Year of Birth ______	Age (Yrs)...	/	9-10
5	How many children are living at home under 10 years of age?	Number of children..... DK.......... NA..........	/ 88 99	11-12
6	How long have you lived at your present address? (______ Years) (______ Months)	Number of months......	/ /	13-15
7	Have you found aircraft flyovers in your neighborhood to be annoying over the past year?	Not at all.. Slightly.... Moderately.. Very........ Extremely... DK.......... NA..........	1 2 3 4 5 8 9	16

Interviewers Initials ________

POST-STUDY QUESTIONNAIRE

Edit Key P.

Item	Question	Response	Code	C.C.
1	Airport Identification ________		/ / / / /	1-4
	Subject: Name ________ Address ________ Phone ________			
2	Subject Identification No. ________	Number......	/ / / /	5-8
3	How annoying were the aircraft flyovers in your neighborhood over the past year?	Not at all.. Slightly.... Moderately.. Very........ Extremely... DK.......... NA..........	1 2 3 4 5 8 9	9
4	How annoying were the aircraft flyovers in your neighborhood during this study?	Not at all.. Slightly.... Moderately.. Very........ Extremely... DK.......... NA..........	1 2 3 4 5 8 9	10
5	About how often were you awakened by aircraft fly-overs during the night during this study? (the interviewer prompts.. "once a week?" ... "once a night?", etc.) (No. of times per wk. __)	Number......	/ /	11-13

POST-STUDY

QUESTIONNAIRE (CONT'D)

Item	Question	Response	Code	C.C.
6	Is this (use the answer from Question 5) typical for the whole year? (If the answer to Question 6 was NO, then ask Question 7)	Yes............... No................	1 2	14-15
7	About how often would you estimate you were awakened by aircraft flyovers during the year? (Number of times per year ________________)	Number...........	/ /	16-18
8	We realize that you may not have been equally annoyed each time you pushed the button. If you could have pushed the button as often as you wanted (instead of just once), according to how bothered or annoyed you were by a particular flyover, how often would you have pushed the button for each flyover during the:	Morning (after awakening)...... Afternoon (after lunch)... Evening (after dinner)......... Night (sleep time)...........	/ / / / / / / / / / / / / / / /	19-22 23-26 27-30 31-34
9	Please estimate your income. Would you say it is between...(read the categories).	\$10-\$15000....... \$15-\$20000....... \$20-\$25000....... \$25-\$30000....... \$30 or more...... DK............... NA...............	1 2 3 4 5 8 9	35

APPENDIX B

NOISE MONITOR INSTRUMENTATION

APPENDIX B

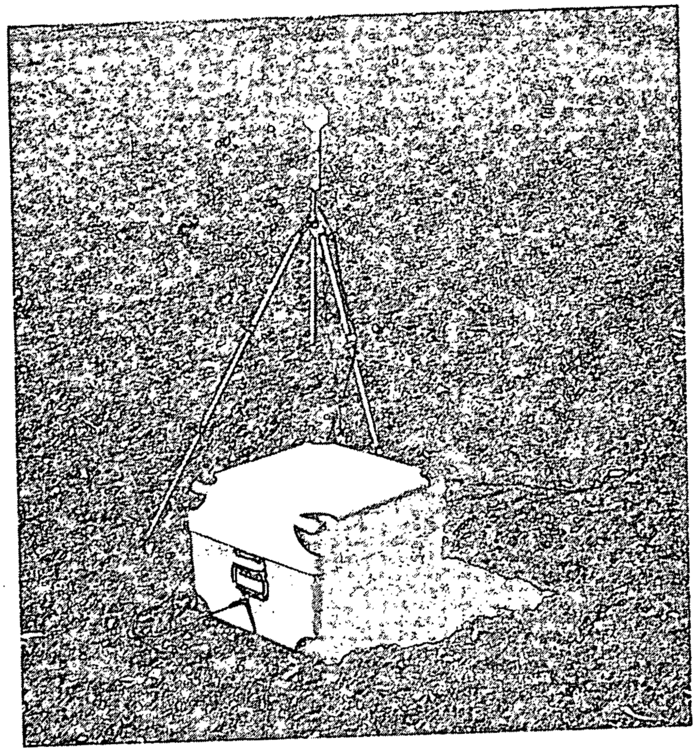
NOISE MONITOR INSTRUMENTATION

The noise monitor unit used in this study is the BBN Model 704, designed especially for unattended monitoring of aircraft and community noise over long periods of time. The unit is capable of operating for several days unattended; however, routine calibration was performed daily in Atlanta and every other day in Burbank to insure data accuracy.

Figure B-1 shows the Model 704 in field service. The unit consists of a General Radio, 1/2 inch electret microphone, monitor control unit and digital cassette tape recorder. The unit also incorporates a small keyboard by which annotation (such as site location, date, instrumentation serial numbers, etc.) may be directly coded on the digital magnetic tape.

The monitor can operate in one of two user-selectable configurations, "time history mode" or "statistical mode", depending upon the particular application involved. In time history mode, the history of individual noise intrusions (such as aircraft flyovers) is retained. Statistical mode provides detailed statistics of hourly sound levels at the expense of losing the identity of individual events. "Time history" mode was used in this study.

The entire system meets Type 1 sound level meter specifications. All data were recorded using the A-weighting network and "slow"



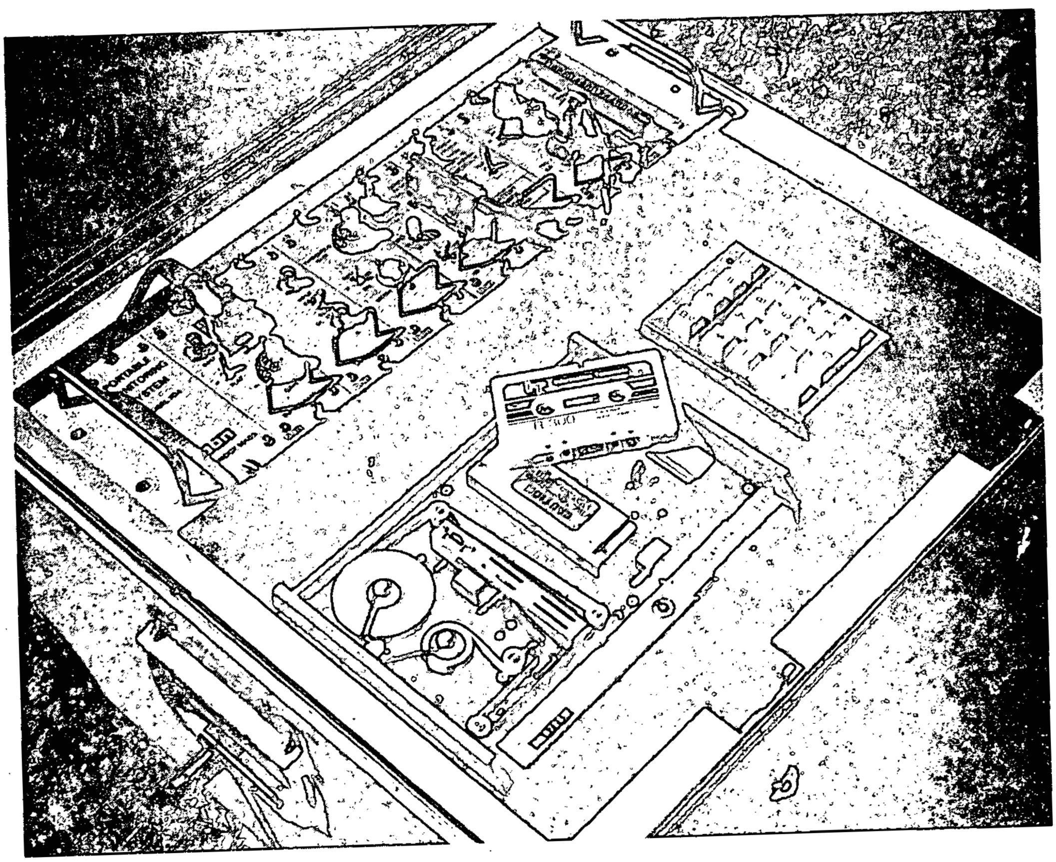
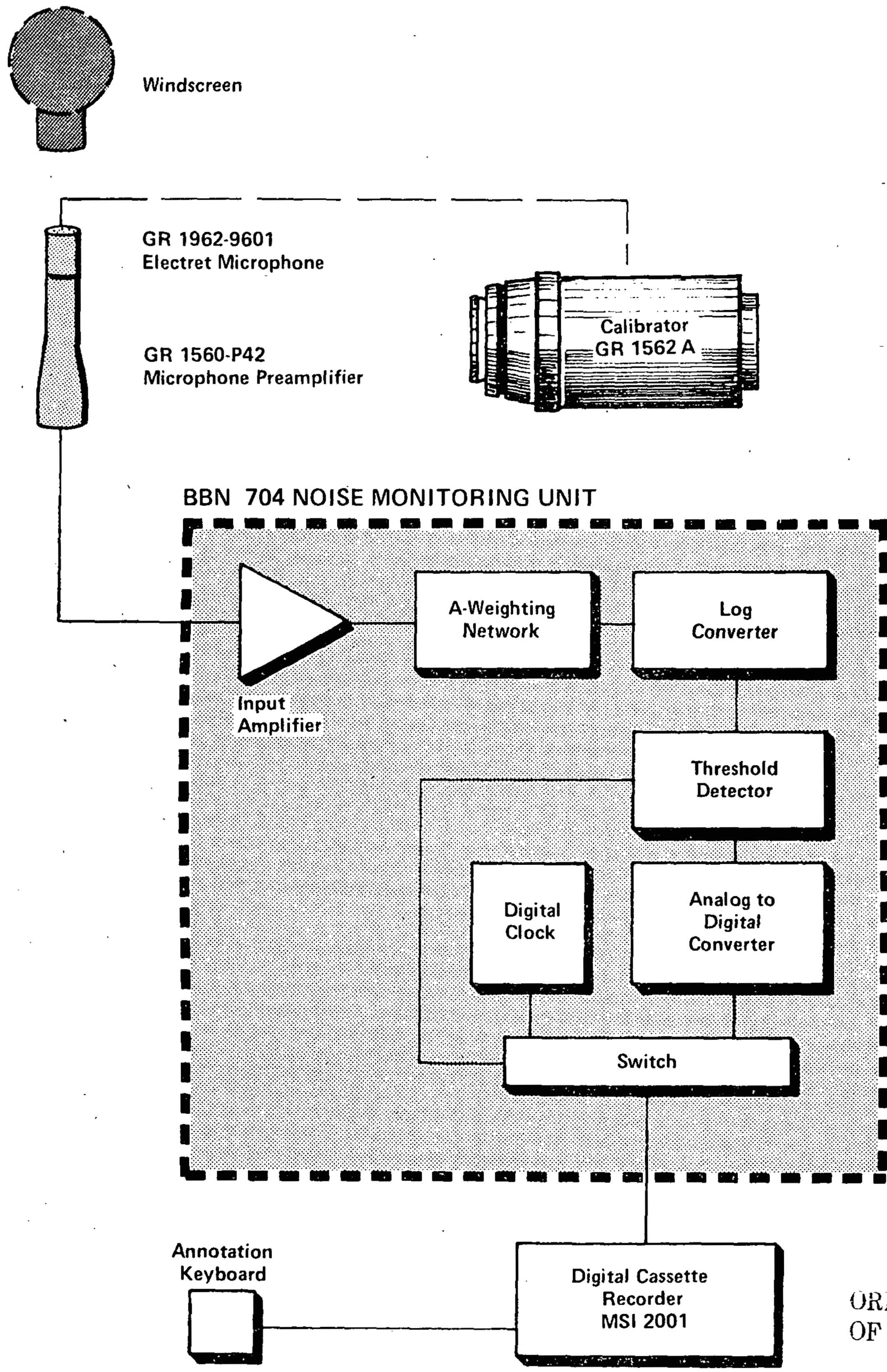


FIGURE B-1. NOISE MONITOR SYSTEM IN FIELD USE meter dynamics. The digital cassettes retrieved from the units were sent to our laboratory for analysis on a digital computer. The summary data provided by the computer forms the heart of the information gathered in this study.

A block diagram of the unit operating in "time history" mode is shown in Figure B-2. In this mode operation is controlled by a user-selectable sound level threshold. During periods when the sound level does not exceed the threshold, the monitor unit remains in a quiescent state. However, when an aircraft or other transient noise intrusion occurs and the sound level rises above the preset threshold value the sound level is digitized and recorded on digital tape. The monitor unit continues to digitize the recording at a one second rate as long as the threshold is exceeded. When the sound level drops below the threshold value, sound level recording ceases and the time-of-day is recorded on the tape (from an internal digital clock). The unit then returns to its quiescent state. In this manner, only significant noise intrusions and their time of occurrence are recorded. This mode of operation is consistent with state airport noise regulations and provides a means for separating the lower level background noise environment from the higher aircraft noise levels. The dynamic range of the instrument is 100 decibels.

The digital tapes recorded by the monitor are processed by a Digital Equipment Corporation PDP-8 computer to provide single event, hourly, and daily statistics.

A typical computer printout is shown in Figure B-3. Note that for each noise intrusion, the time of day, the maximum level,



ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE B-2. BLOCK DIAGRAM OF NOISE MONITORING INSTRUMENTATION

TIME	MAX	DUR	SENEL
16:16.9	78.0	26	86.9
	77.0	22	87.8
16:28.1	77.0	3	79.2
16:33.2	96.0	11	104.3
16:35.0	77.0	23	88.1
<16:35.1	71.0	4	75.6
16:49.5	78.0	14	86.5

$ HNL (1600 TO 1659) = 69.1

TIME	MAX	DUR	SENEL
17:01.3	78.0	29	88.4
17:17.3	81.0	13	88.6
17:25.9	82.0	29	91.3
<17:35.0	75.0	14	81.5
<17:35.1	72.0	6	77.6

$ HNL (1700 TO 1759) = 59.3

TIME	MAX	DUR	SENEL
18:05.8	76.0	21	85.7
<18:11.6	72.0	8	79.1
<18:16.5	66.0	2	69.1
18:21.2	78.0	16	88.3
<18:41.7	72.0	7	79.4

$ HNL (1800 TO 1859) = 55.5

TIME	MAX	DUR	SENEL
19:17.0	75.0	24	85.4
<19:17.3	75.0	12	80.8
<19:17.3	69.0	2	71.7
19:24.5	76.0	19	85.2
19:24.8	75.0	8	82.9
19:29.8	80.0	17	88.5
19:33.0	78.0	21	88.5
	77.0	32	88.6
19:39.6	75.0	30	85.9

$ HNL (1900 TO 1959) = 60.0

TIME	MAX	DUR	SENEL
20:10.9	76.0	48	90.4
20:54.1	78.0	22	88.6

$ HNL (2000 TO 2059) = 57.1

FIGURE B-3. TYPICAL COMPUTER OUTPUT FROM NOISE MONITOR SYSTEM the time duration for which the level is within 10 decibels of the maximum value, and the single event noise exposure level (SENEL) are tabulated. In addition the hourly noise level (HNL) is tabulated at the end of each hour. Finally, at the end of each day, the community noise equivalent level (CNEL) and day-night average level (L_{dn}) are listed.

The effect of the digitization process on computed sound exposure level (SEL) accuracy is shown in Figure B-4. Within the monitor, the output of the microphone is converted by analog circuitry to a time-varying DC voltage proportional to the A-weighted, slow-response sound level in decibels. At a fixed period rate (in this study once per second), the instantaneous DC voltage is digitized (in this study to a resolution of one decibel) and recorded on digital tape. Later, the tape is processed by a digital computer which computes the sound exposure level of each noise event by an energy summation of these digitized levels. Figure B-4 shows the ± 95 percent confidence interval on the computed SEL as a function of signal duration 10 dB down from the maximum value at 3 different digitization rates (the middle curve applies to this study). Basically, the graph ascribes numerical values to common sense expectations. At very long durations (e.g., 60 seconds or greater) the signal rises and decays slowly with time, and the probable error is less than ± 0.1 dB due to the large number of individual sound levels incorporated in the summation. In contrast, the probable error increases for short duration (fast rise/decay) signals since fewer digitized sound levels contribute to the sum. In this case the value of the sum becomes more sensitive to the precise instant at which the sound level was digitized by the monitor.

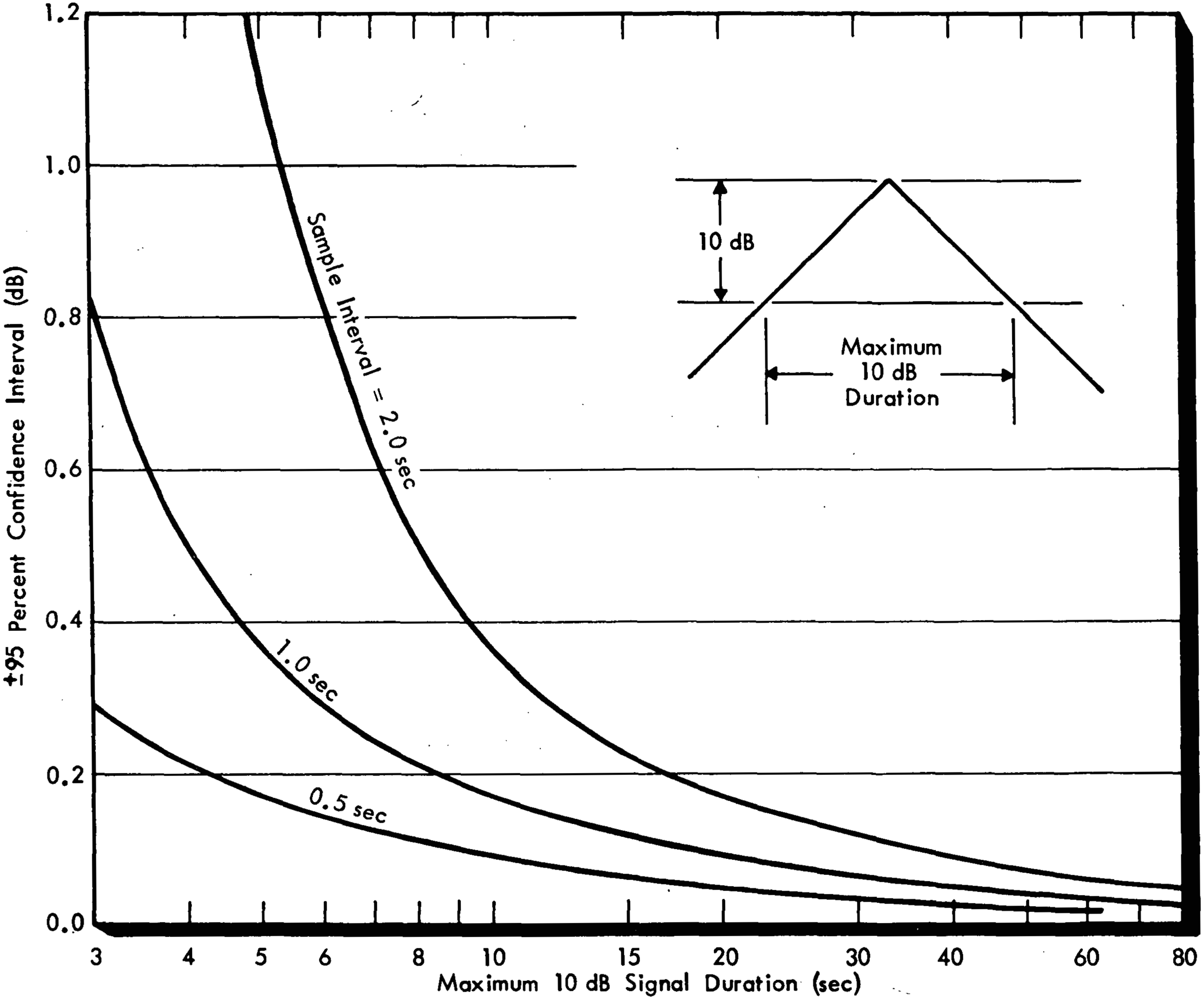


FIGURE B-4. SOUND EXPOSURE LEVEL COMPUTATIONAL ERROR BOUNDS DUE TO FINITE SAMPLING RATE (1 dB SPL RESOLUTION)

All things considered, however, the 95 percent confidence interval does not grow excessively large even for relatively short durations. For example, the interval is less than $\pm$ 0.5 dB for all durations in excess of four seconds. By way of comparison, a review of the noise monitor data at sites nearest the airport reveals that durations less than six or seven seconds are rarely observed.

APPENDIX C

NOISE ENVIRONMENT STATISTICS

APPENDIX C

NOISE ENVIRONMENT STATISTICS

Appendix C provides a detailed description of the noise environment in each of the four respondent communities involved in this study. In each community a single, centrally located noise monitor (described in Appendix B) recorded aircraft noise levels. The monitor provided information on the time of occurrence, maximum A-level, and sound exposure level of each aircraft noise intrusion during the study. The following data is compiled from the noise monitor records.

Figure C-1 shows the distribution of aircraft activity over the course of the day. Clearly illustrated is the substantial difference in evening and nighttime activity between the Burbank and Atlanta communities. At Burbank, there is no commercial jet aircraft activity before 7 a.m., nor after 10 p.m. At Atlanta, there is substantial activity from 5 p.m. until 1:30 a.m. the following morning. In fact, at Site 4585, 15 percent of the aircraft activity occurred between 10 p.m. and 7 a.m., and at Site 3996, 25 percent of the activity occurred during the same period.

Figure C-1 depicts total aircraft operations without regard to the size of the aircraft or the noise level it produced. Figures C-2, C-3, C-4, and C-5 provide the noise level information for each of the four communities. Each of these figures shows the distribution of sound exposure levels from individual events occurring within four different time periods of the day. Two immediate observations may be made. First, for any one community, the relative distribution of sound levels remains essentially constant over the entire day. Second, the distribution of levels at all sites tends to be bimodal (most pronounced at Burbank). For the Burbank communities, the aircraft noise environment is dictated almost exclusively by departures, and the bimodality arises from the mix of general aviation propeller aircraft and commercial jets (B-727's, B-737's and DC-9's). At Atlanta, the aircraft activity is almost exclusively commercial jets, and the bimodality arises out of the mix of arrivals and departures overflying the community.

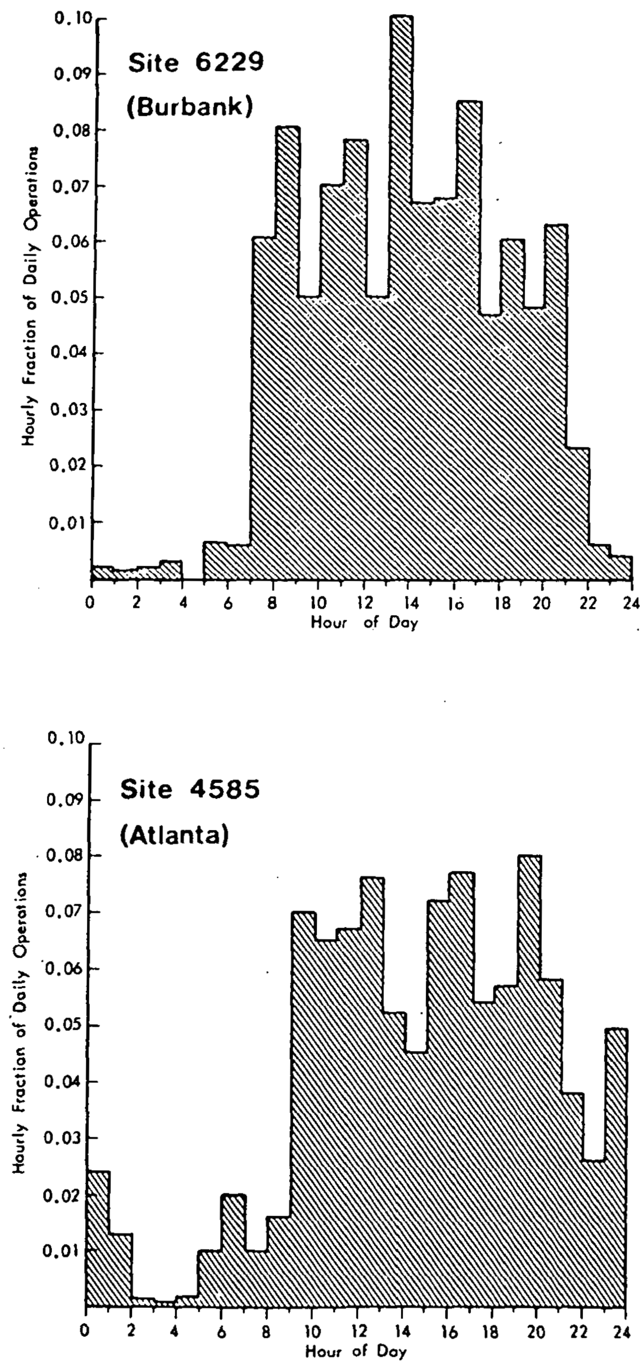


FIGURE C-1. HOURLY DISTRIBUTIONS OF AIRCRAFT FLIGHT ACTIVITY

ORIGINAL PAGE IS
OF POOR QUALITY

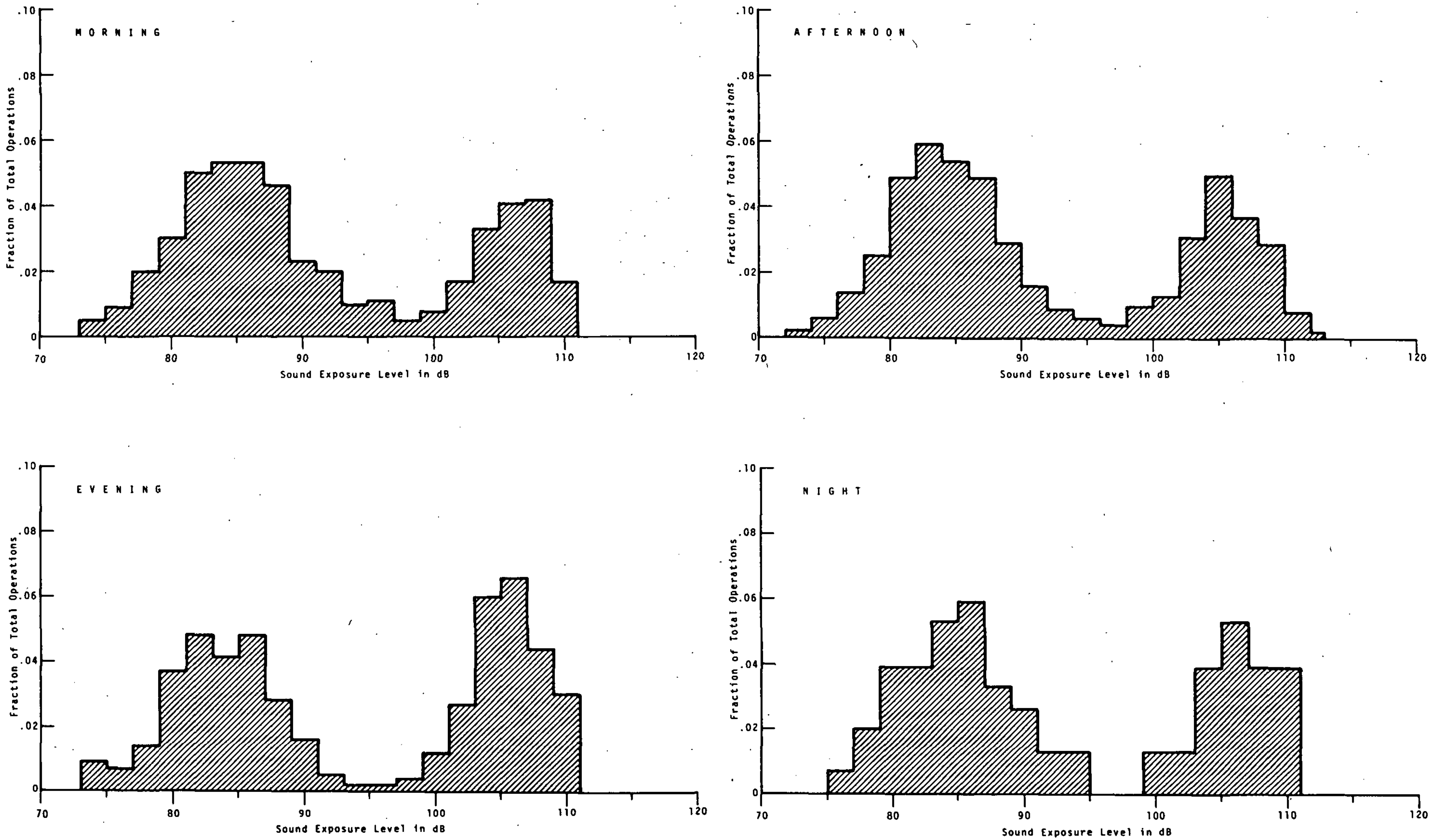


FIGURE C-2. DISTRIBUTION OF AIRCRAFT SOUND EXPOSURE LEVELS AT NOISE MEASUREMENT SITE 2036 (COMMUNITY A)

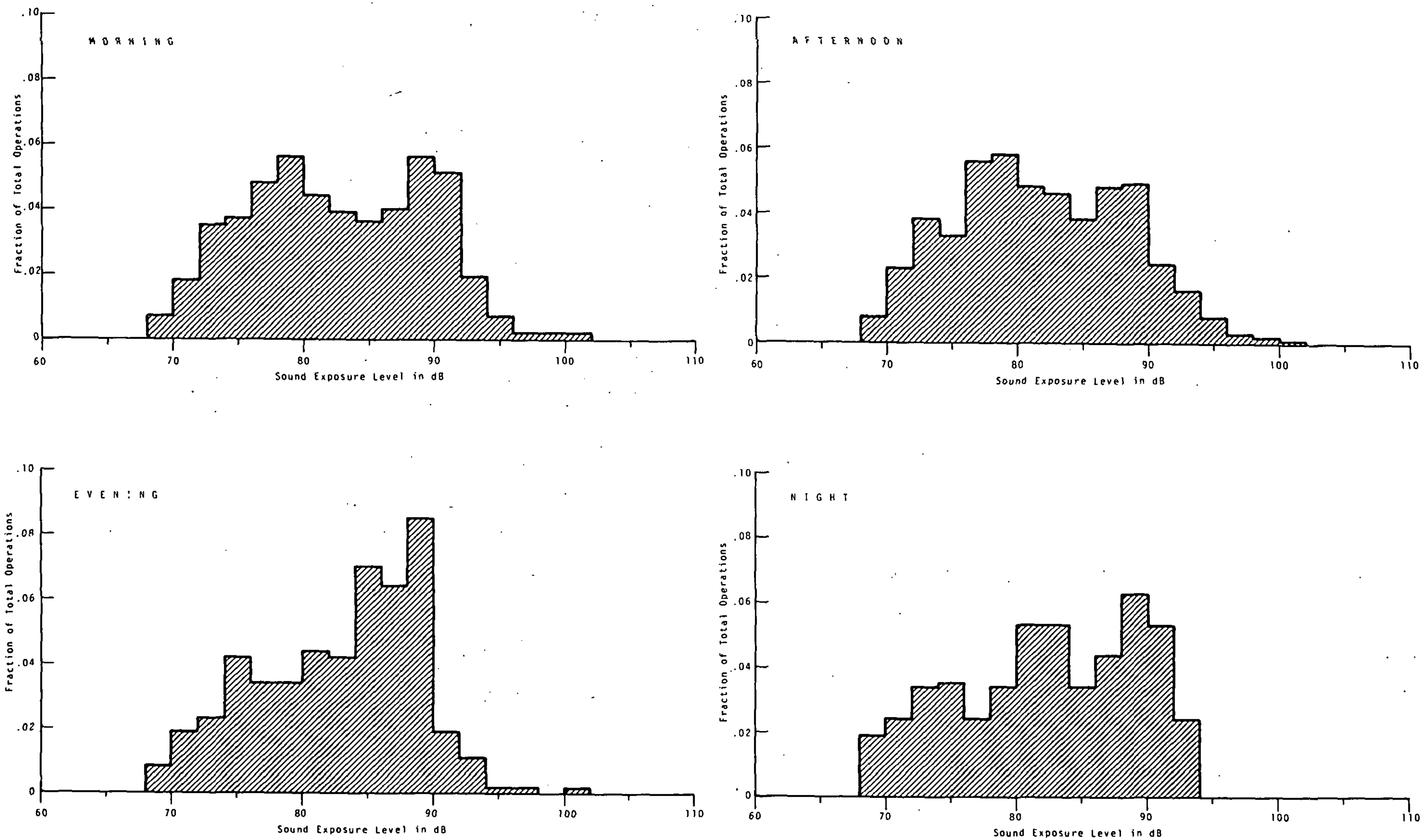


FIGURE C-3. DISTRIBUTION OF AIRCRAFT SOUND EXPOSURE LEVELS AT NOISE MEASUREMENT SITE 6229 (COMMUNITY B)

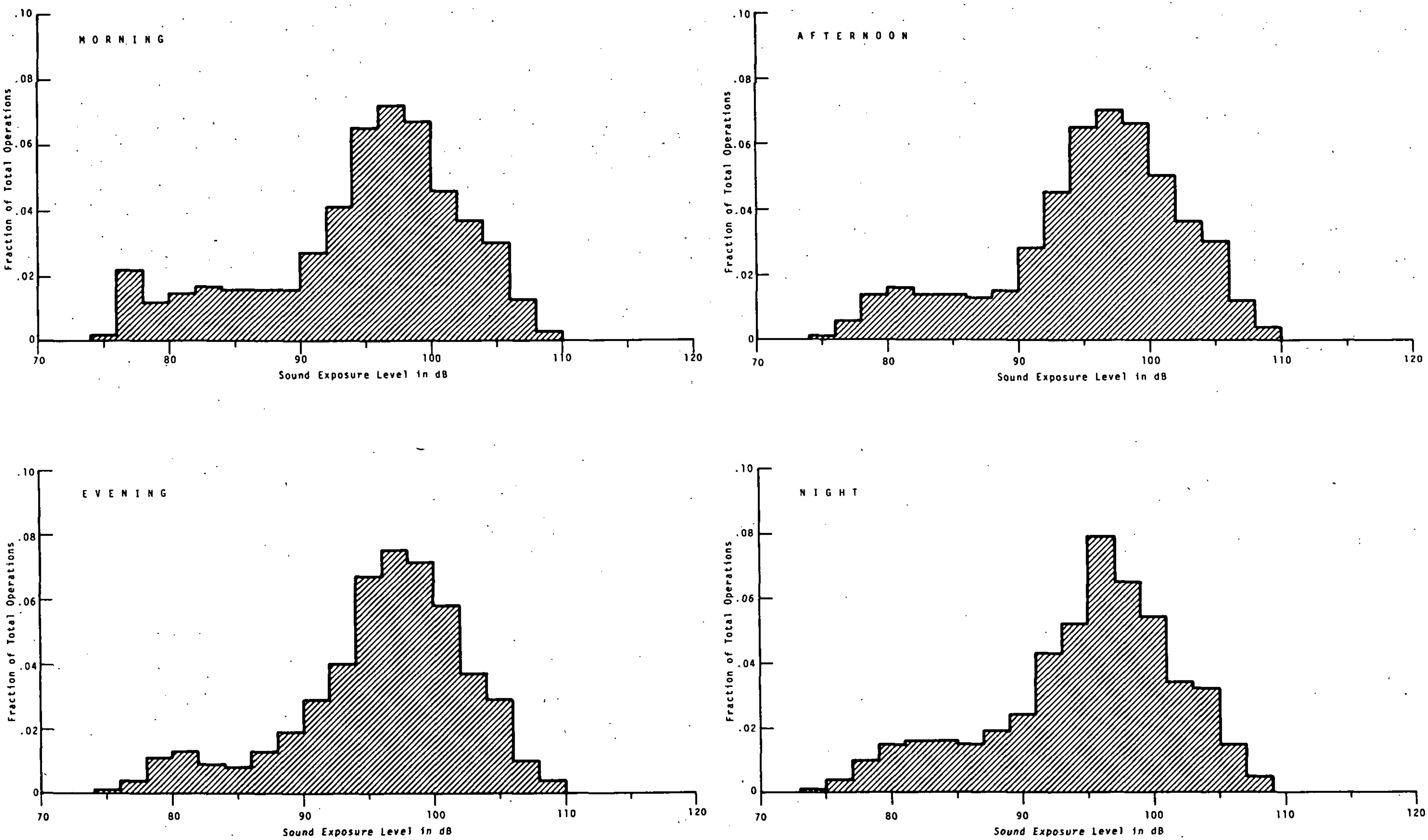


FIGURE C-4. DISTRIBUTION OF AIRCRAFT SOUND EXPOSURE LEVELS AT NOISE MEASUREMENT SITE 4585 (COMMUNITY C)

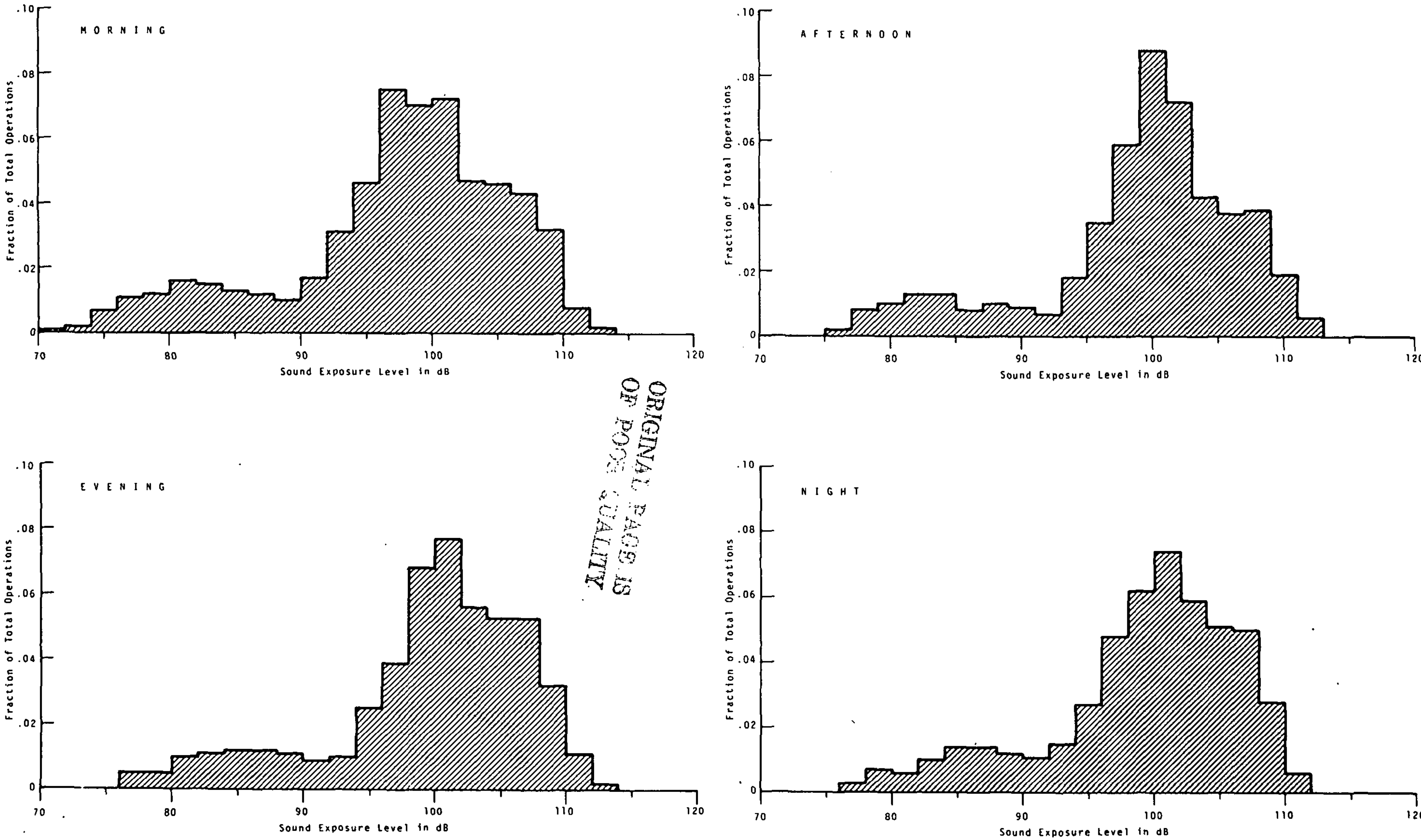


FIGURE C-5. DISTRIBUTION OF AIRCRAFT SOUND EXPOSURE LEVELS AT NOISE MEASUREMENT SITE 3996 (COMMUNITY D)

APPENDIX D

TABULATIONS OF RESPONSE DATA

TABLE D-I ESTIMATED ANNOYANCE THRESHOLDS IN TERMS OF SOUND EXPOSURE LEVEL (SEL)

Respondent	Morning 0630-1230	Afternoon 1130-1930	Daytime 0630-1930	Evening 1800-0100	Night 2130-0730
COMMUNITY A (BURBANK, CA.)					
002	109.33	106.43	107.29	107.73	--
004	105.13	103.29	103.42	105.33	--
005	89.21	87.00	87.77	89.00	--
006	106.00	105.72	105.80	105.33	--
009	104.50	90.50	93.86	102.00	--
010	97.00	89.39	90.76	91.00	--
011	95.67	103.00	100.56	103.13	--
013	92.54	89.42	90.81	99.50	--
014	95.75	90.24	91.77	103.17	--
015	92.33	90.36	90.79	99.33	--
COMMUNITY B (BURBANK, CA.)					
016	84.00	85.28	85.42	85.00	--
017	85.72	85.41	85.53	84.80	--
018	78.75	81.29	81.33	83.33	--
019	98.75	98.42	99.19	96.20	--
021	96.25	95.18	95.92	95.55	--
024	85.63	85.40	85.25	84.33	--
COMMUNITY C (ATLANTA, GA.)					
201	97.06	96.80	96.90	97.90	100.67
202	91.83	91.25	91.75	91.78	98.21
203	90.08	88.35	88.43	90.85	95.60
204	99.06	99.32	99.41	100.28	100.53
205	105.52	104.91	105.31	104.01	105.73
207	104.64	105.12	105.00	102.60	99.24
208	95.73	95.29	95.47	95.41	99.32
211	98.64	99.11	99.17	97.86	99.91
212	98.90	98.13	98.52	99.29	100.15
213	100.37	97.44	98.20	97.43	99.07
214	98.49	97.67	97.51	97.70	99.36

TABLE D-1 ESTIMATED ANNOYANCE THRESHOLDS IN TERMS OF SOUND EXPOSURE LEVEL (SEL) (CONT'D)

Respondent	Morning 0630-1230	Afternoon 1130-1930	Daytime 0630-1930	Evening 1800-0100	Night 2130-0730
COMMUNITY D (ATLANTA, GA.)					
216	106.21	108.26	108.12	106.83	107.94
222	107.83	108.70	108.50	108.91	108.88
223	105.87	102.17	103.52	105.31	106.00
224	102.94	104.49	104.20	104.91	104.10
225	100.06	97.84	98.87	98.24	104.64
226	107.57	108.56	108.37	108.07	107.31
227	104.94	104.76	105.20	102.53	101.45
228	96.29	96.75	96.44	97.53	98.06
229	99.11	99.12	99.12	100.31	101.40
230	100.38	100.88	100.21	103.51	104.10
231	97.13	98.51	97.25	98.23	100.57
232	94.71	96.69	96.65	99.78	--
233	99.59	99.11	99.28	99.89	105.10
234	104.20	105.48	105.31	104.24	105.24
235	102.33	105.36	104.98	105.08	104.75
237	104.63	107.69	105.55	104.35	106.52
238	102.26	101.94	102.17	104.34	104.50
239	107.47	108.14	108.55	108.71	109.50
240	106.50	102.62	106.92	106.68	107.69

TABLE D-II ESTIMATED ANNOYANCE THRESHOLDS IN TERMS OF MAXIMUM A-WEIGHTED SOUND LEVEL

Respondent	Morning 0630-1230	Afternoon 1130-1930	Daytime 0630-1930	Evening 1800-0100	Night 2130-0730
COMMUNITY A (BURBANK, CA.)					
002	103.06	100.28	101.17	101.73	--
004	98.50	96.55	96.63	99.00	--
005	83.27	81.26	81.88	83.50	--
006	99.56	99.31	99.30	99.00	--
009	97.78	85.14	88.38	94.00	--
010	91.60	84.09	85.47	86.67	--
011	90.00	96.09	93.57	97.07	--
013	87.45	84.10	85.56	91.50	--
014	90.20	84.95	86.23	96.83	--
015	87.18	85.11	85.63	91.50	--
COMMUNITY B (BURBANK, CA.)					
016	77.33	77.51	77.84	76.25	--
017	78.14	77.69	77.86	75.97	--
018	74.28	74.93	75.16	75.00	--
019	89.00	89.50	89.68	86.20	--
021	86.67	86.19	86.67	85.13	--
024	76.96	76.67	76.78	74.80	--
COMMUNITY C (ATLANTA, GA.)					
201	90.27	90.01	90.23	90.87	93.11
202	84.38	84.39	84.69	84.18	90.33
203	83.32	82.54	82.53	83.13	87.18
204	91.92	92.22	92.26	92.93	93.29
205	97.65	97.46	97.72	95.94	97.81
207	96.85	97.41	97.38	94.97	91.48
208	88.94	88.57	88.74	88.22	92.22
211	91.91	92.13	92.32	90.88	93.00
212	91.43	91.04	91.29	91.24	91.82
213	93.48	90.80	91.55	90.08	91.45
214	91.50	91.03	90.86	90.75	91.73

TABLE D-II ESTIMATED ANNOYANCE THRESHOLDS IN TERMS OF MAXIMUM A-WEIGHTED SOUND LEVEL (CONT'D)

Respondent	Morning 0630-1230	Afternoon 1130-1930	Daytime 0630-1930	Evening 1800-0100	Night 2130-0730
		COMMUNITY D (ATLANTA, GA.)			
216	99.98	101.85	101.69	100.02	101.07
222	101.57	102.59	102.26	102.66	102.38
223	99.66	97.10	97.66	98.51	98.97
224	96.31	97.76	97.34	98.13	96.73
225	93.90	91.37	92.88	91.83	97.33
226	100.85	102.20	101.90	101.34	100.05
227	97.94	97.58	97.98	95.70	94.91
228	90.44	90.33	90.38	91.60	90.80
229	92.89	92.41	92.97	93.90	93.44
230	94.81	95.27	94.78	97.21	96.72
231	91.10	92.46	91.33	92.10	93.42
232	88.76	90.17	90.30	92.44	--
233	93.40	92.62	92.93	92.97	97.00
234	97.83	98.99	98.78	97.47	98.33
235	96.48	98.37	97.92	97.90	97.29
237	97.27	100.38	98.11	98.13	98.81
238	96.66	95.39	96.01	96.91	98.03
239	100.95	101.05	101.46	101.64	102.33
240	100.91	98.58	100.71	99.88	100.80

TABLE D-III CUMULATIVE SOUND EXPOSURE AND CUMULATIVE ANNOYANCE

	PERIOD OF DAY									
	Morning 0630-1230		Afternoon 1130-1930		Daytime 0630-1930		Evening 1800-0100		Night 2130-0730	
Respondent	Number of Responses	Energy (dB)	Number of Responses	Energy (dB)	Number of Responses	Energy (dB)	Number of Responses	Energy (dB)	Number of Responses	Energy (dB)
COMMUNITY A (BURBANK, CA.)										
002	34	128.4	103	130.5	143	132.8	41	128.0	--	--
004	43	125.2	107	127.7	190	130.5	23	122.3	--	--
005	207	129.6	386	131.0	608	133.5	117	127.2	--	--
006	121	130.9	148	131.3	288	134.4	59	126.7	--	--
009	113	129.1	308	130.6	409	132.8	92	126.4	--	--
010	91	127.1	273	130.0	375	131.8	112	126.5	--	--
011	153	129.2	177	129.6	359	132.7	79	126.3	--	--
013	219	130.1	307	130.3	514	133.2	116	127.2	--	--
014	183	129.0	316	130.7	514	133.4	86	126.6	--	--
015	171	129.2	312	130.6	472	132.9	125	127.3	--	--
COMMUNITY B (BURBANK, CA.)										
016	84	111.0	253	117.0	364	118.5	122	111.7	--	--
017	221	116.0	246	116.9	467	119.5	144	112.8	--	--
018	98	109.5	281	115.7	431	117.6	52	107.5	--	--
019	21	118.7	37	121.1	61	124.1	18	115.0	--	--
021	15	111.9	65	119.2	90	121.3	20	113.2	--	--
024	91	111.1	133	113.4	232	115.3	94	108.7	--	--

TABLE D-III CUMULATIVE SOUND EXPOSURE AND CUMULATIVE ANNOYANCE (CONT'D)

	Period of Day									
	Morning 0630-1230		Afternoon 1130-1930		Daytime 0630-1930		Evening 1800-0100		Night 2130-0730	
Respondent	Number of Responses	Energy (dB)	Number of Responses	Energy (dB)	Number of Responses	Energy (dB)	Number of Responses	Energy (dB)	Number of Responses	Energy (dB)
COMMUNITY C (ATLANTA, GA.)										
201	960	132.5	1568	134.3	2699	136.8	852	132.3	24	119.7
202	1254	132.4	2046	134.3	3032	136.1	1702	133.3	275	127.9
203	731	129.9	1592	133.0	2449	134.9	829	129.7	175	123.5
204	441	130.9	943	134.5	1372	136.2	563	132.8	51	123.2
205	50	129.1	223	135.1	301	136.7	225	133.3	29	128.7
207	129	131.7	144	132.4	245	135.1	218	131.3	106	124.9
208	865	131.2	1502	133.3	2308	135.3	1045	131.9	220	127.9
211	394	130.1	920	133.9	1684	136.8	475	129.6	53	123.0
212	611	132.2	768	132.6	1380	135.5	594	132.2	314	130.4
213	547	132.7	1477	134.8	2309	137.4	1139	133.3	218	127.9
214	379	129.5	1088	133.4	1881	135.7	903	132.5	338	129.7
COMMUNITY D (ATLANTA, GA.)										
216	136	133.1	143	136.0	314	139.1	116	133.2	141	135.7
222	99	134.6	125	137.7	215	139.4	44	134.3	14	130.8
223	87	130.2	327	133.7	772	137.8	215	132.9	177	133.4
224	136	130.6	152	133.2	284	135.3	63	130.4	65	129.7
225	874	134.8	1626	136.5	2321	138.6	841	133.6	324	134.4
226	27	130.3	89	137.0	112	137.7	100	136.0	83	134.9
227	169	132.6	370	135.7	555	137.9	524	134.8	420	132.7
228	820	131.4	872	132.9	1299	134.0	603	131.4	586	131.2
229	543	132.0	572	132.9	1227	135.9	655	133.5	67	123.9
230	450	132.3	443	132.9	1052	136.2	215	131.8	225	132.1
231	559	130.6	924	134.6	1763	136.2	822	133.3	196	128.4
232	413	128.2	789	132.4	1476	135.0	354	130.0	--	--
233	668	133.7	1230	136.3	1780	138.0	766	134.4	34	124.1
234	175	132.1	206	134.6	367	136.7	297	134.0	151	133.7
235	247	131.7	252	134.7	487	136.9	240	133.8	105	130.4
237	604	137.2	140	134.6	1022	140.5	65	127.7	56	129.6
238	133	129.0	339	133.2	813	137.0	297	133.7	90	129.7
239	59	131.5	53	132.3	189	138.1	31	130.4	17	131.1
240	15	125.9	17	122.8	33	129.5	31	128.8	19	126.9

TABLE D-IV ESTIMATED UNIT ANNOYANCE SOUND EXPOSURE LEVEL

Respondent	Morning 0630-1230	Afternoon 1130-1930	Daytime 0630-1930	Evening 1800-0100	Night 2130-0730
		COMMUNITY A (BURBANK, CA.)			
002	113.09	110.37	111.25	111.87	--
004	108.87	107.41	107.71	108.68	--
005	106.44	105.13	105.66	106.52	--
006	110.07	109.60	109.81	108.99	--
009	108.57	105.71	106.68	106.76	--
010	107.51	105.64	106.06	106.01	--
011	107.35	107.12	107.15	107.32	--
013	106.70	105.43	106.09	106.56	--
014	106.38	105.70	106.29	107.26	--
015	106.87	105.66	106.16	106.33	--
		COMMUNITY B (BURBANK, CA.)			
016	91.76	92.97	92.89	90.84	--
017	92.56	92.99	92.81	91.22	--
018	89.59	91.21	91.26	90.34	--
019	105.48	105.42	106.25	102.45	--
021	100.14	101.07	101.76	100.19	--
024	91.51	92.16	91.65	88.97	--
		COMMUNITY C (ATLANTA, GA.)			
201	102.68	102.35	102.49	103.00	105.90
202	101.42	101.19	101.28	100.99	103.51
203	101.26	100.98	101.01	100.51	101.07
204	104.46	104.75	104.83	105.29	106.12
205	112.11	111.62	111.91	109.78	114.08
207	110.59	110.82	111.21	107.92	104.65
208	101.83	101.53	101.67	101.71	104.48
211	104.15	104.26	104.54	102.83	105.76
212	104.34	103.75	104.10	104.46	105.43
213	105.32	103.11	103.77	102.73	104.52
214	103.71	103.03	102.96	102.94	104.41

TABLE D-IV ESTIMATED UNIT ANNOYANCE SOUND EXPOSURE LEVEL (CONT'D)

Respondent	Morning 0630-1230	Afternoon 1130-1930	Daytime 0630-1930	Evening 1800-0100	Night 2130-0730
			COMMUNITY D (ATLANTA, GA.)		
216	111.76	114.45	114.13	112.56	114.21
222	114.64	116.73	116.08	117.87	119.34
223	110.80	108.55	108.92	109.58	110.92
224	109.26	111.38	110.77	112.41	111.57
225	105.38	104.39	104.94	104.35	109.29
226	115.99	117.51	117.21	116.00	115.71
227	110.32	110.02	110.46	107.61	106.47
228	102.26	103.49	102.86	103.60	103.52
229	104.65	105.33	105.01	105.34	105.64
230	105.77	106.44	105.98	108.48	108.58
231	103.13	104.94	103.74	104.15	105.48
232	102.04	103.43	103.31	104.51	--
233	105.45	105.40	105.50	105.56	108.79
234	109.67	111.46	111.05	109.27	111.91
235	107.77	110.69	110.02	110.00	110.19
237	109.39	113.14	110.41	109.57	112.12
238	107.76	107.90	107.90	108.97	110.16
239	113.79	115.06	115.34	115.49	118.80
240	114.14	110.50	114.31	113.89	114.11

C-2

TABLE E-I DIFFERENCES IN ESTIMATED ANNOYANCE THRESHOLDS IN TERMS OF SOUND EXPOSURE LEVEL

Respondent	Eve-Day	Night-Day	Aft-Morn	Eve-Morn	Night-Morn	Eve-Aft	Night-Aft	Night-Eve
COMMUNITY A (BURBANK, CA.)								
002	.44	--	- 2.90	- 1.60	--	1.30	--	--
004	1.91	--	- 1.84	.20	--	2.04	--	--
005	1.23	--	- 2.21	- .21	--	2.00	--	--
006	- .47	--	- .28	- .67	--	- .39	--	--
009	8.14	--	-14.00	- 2.50	--	11.50	--	--
010	.24	--	- 7.61	- 6.00	--	1.61	--	--
011	2.57	--	7.33	7.46	--	.13	--	--
013	8.69	--	- 3.12	6.96	--	10.08	--	--
014	11.40	--	- 5.51	7.42	--	12.93	--	--
015	8.54	--	- 1.97	7.00	--	8.97	--	--
$\overline{X}$	4.27*	--	- 3.21	1.81	--	5.02*	--	--
σ	4.41	--	5.43	4.95	--	5.19	--	--
N	10	--	10	10	--	10	--	--
COMMUNITY B (BURBANK, CA.)								
016	- .42	--	1.28	1.00	--	- .28	--	--
017	- .73	--	- .31	- .92	--	- .61	--	--
018	2.00	--	2.54	4.58	--	2.04	--	--
019	- 2.99	--	- .33	- 2.55	--	- 2.22	--	--
021	- .37	--	- 1.07	- .70	--	.37	--	--
024	- .92	--	- .23	- 1.30	--	- 1.07	--	--
$\overline{X}$	- .57	--	.31	.02	--	- .30	--	--
σ	1.59	--	1.33	2.51	--	1.44	--	--
N	6	--	6	6	--	6	--	--

*Indicates mean value differs from zero at .05 level of confidence.

TABLE E-I DIFFERENCES IN ESTIMATED ANNOYANCE THRESHOLDS IN TERMS OF SOUND EXPOSURE LEVEL (CONT'D)

Respondent	Eve-Day	Night-Day	Aft-Morn	Eve-Morn	Night-Morn	Eve-Aft	Night-Aft	Night-Eve
				COMMUNITY C (ATLANTA, GA.)				
201	1.00	3.77	- .26	.84	3.61	1.10	3.87	2.77
202	.03	6.46	- .58	- .05	6.38	.53	6.96	6.43
203	2.42	7.17	- 1.73	.77	5.52	2.50	7.25	4.75
204	.87	1.12	.26	1.22	1.47	.96	1.21	.25
205	- 1.30	.42	- .61	- 1.51	.21	- .90	.82	1.72
207	- 2.40	- 5.76	.48	- 2.04	- 5.40	- 2.52	- 5.88	- 3.36
208	- .06	3.85	- .44	- .32	3.59	.12	4.03	3.91
211	- 1.31	.74	.47	- .78	1.27	- 1.25	.80	2.05
212	.77	1.63	- .77	.39	1.25	1.16	2.02	.86
213	- .77	.87	- 2.93	- 2.94	- 1.30	- .01	1.63	1.64
214	.19	1.85	- .82	- .79	.87	.03	1.69	1.66
$\overline{X}$	- .05	2.01	- .63	- .47	1.59	.16	2.22	2.06*
σ	1.34	3.46	1.00	1.30	3.26	1.36	3.54	2.55
N	11	11	11	11	11	11	11	11

*Indicates mean value differs from zero at .05 level of confidence.

TABLE E-I DIFFERENCES IN ESTIMATED ANNOYANCE THRESHOLDS IN TERMS OF SOUND EXPOSURE LEVEL (CONT'D)

Respondent	Eve-Day	Night-Day	Aft-Morn	Eve-Morn	Night-Morn	Eve-Aft	Night-Aft	Night-Eve
				COMMUNITY D (ATLANTA, GA.)				
216	-1.29	-.18	2.05	.62	1.73	-1.43	-.32	1.11
222	.41	.38	.87	1.08	1.05	.21	.18	-.03
223	1.79	2.48	-3.70	-.56	.13	3.14	3.83	.69
224	.71	-.10	1.55	1.97	1.16	.42	-.39	-.81
225	-.63	5.77	-2.22	-1.82	4.58	.40	6.80	6.40
226	-.30	-1.06	.99	.50	-.26	-.49	-1.25	-.76
227	-2.67	-3.75	-.18	-2.41	-3.49	-2.23	-3.31	-1.08
228	1.09	1.62	.46	1.24	1.77	.78	1.31	.53
229	1.19	2.28	.01	1.20	2.29	1.19	2.28	1.09
230	3.30	3.89	.50	3.13	3.72	2.63	3.22	.59
231	.98	3.32	1.38	1.10	3.44	-.28	2.06	2.34
232	3.13	--	1.98	5.07	--	3.09	--	--
233	.61	5.82	-.48	.30	5.51	.78	5.99	5.21
234	-1.07	-.07	1.28	.04	1.04	-1.24	-.24	1.00
235	.10	-.23	3.03	2.75	2.42	-.28	-.61	-.33
237	-1.20	.97	3.06	-.28	1.89	-3.34	-1.17	2.17
238	2.17	2.33	-.32	2.08	2.24	2.40	2.56	.16
239	.16	.95	.67	1.24	2.03	.57	1.36	.79
240	-.24	.77	-3.88	.18	1.19	4.06	5.07	1.01
$\bar{X}$	.43	1.40*	.37	.92*	1.80*	.55	1.52*	1.12*
σ	1.52	2.37	1.92	1.71	1.97	1.92	2.72	1.95
N	19	18	19	19	18	19	18	18
				ALL RESPONDENTS				
$\bar{X}$	1.02*	1.63*	-.65	.66	1.72*	1.32*	1.79*	1.47*
σ	2.93	2.79	3.13	2.80	2.48	3.39	3.01	2.20
N	46	29	46	46	29	46	29	29

*Indicates mean value differs from zero at .05 level of confidence.

TABLE E-II DIFFERENCES IN ESTIMATED ANNOYANCE THRESHOLDS IN TERMS OF MAXIMUM A-WEIGHTED SOUND LEVEL

Respondent	Eve-Day	Night-Day	Aft-Morn	Eve-Morn	Night-Morn	Eve-Aft	Night-Aft	Night-Eve
COMMUNITY A (BURBANK, CA.)								
002	.56	--	- 2.78	- 1.33	--	1.45	--	--
004	2.37	--	- 1.95	.50	--	2.45	--	--
005	1.62	--	- 2.01	.23	--	2.24	--	--
006	- .30	--	- .25	- .56	--	- .31	--	--
009	5.62	--	-12.64	- 3.78	--	8.86	--	--
010	1.20	--	- 7.51	- 4.93	--	2.58	--	--
011	3.50	--	6.09	7.07	--	.98	--	--
013	5.94	--	- 3.35	4.05	--	7.40	--	--
014	10.60	--	- 5.25	6.63	--	11.88	--	--
015	5.87	--	- 2.07	4.32	--	6.39	--	--
$\bar{X}$	3.70*	--	- 3.17	1.22	--	4.39*	--	--
σ	3.32	--	4.85	4.15	--	3.99	--	--
N	10	--	10	10	--	10	--	--
COMMUNITY B (BURBANK, CA.)								
016	- 1.59	--	.18	- 1.08	--	- 1.26	--	--
017	- 1.89	--	- .45	- 2.17	--	- 1.72	--	--
018	- .16	--	.65	.72	--	.07	--	--
019	- 3.48	--	.50	- 2.80	--	- 3.30	--	--
021	- 1.54	--	- .48	- 1.54	--	- 1.06	--	--
024	- 1.98	--	- .29	- 2.16	--	- 1.87	--	--
$\bar{X}$	- 1.77*	--	.02	- 1.51*	--	- 1.52*	--	--
σ	1.06	--	.49	1.24	--	1.11	--	--
N	6	--	6	6	--	6	--	--

*Indicates mean value differs from zero at .05 level of confidence.

TABLE E-II DIFFERENCES IN ESTIMATED ANNOYANCE THRESHOLDS IN TERMS OF MAXIMUM A-WEIGHTED SOUND LEVEL (CONT'D)

Respondent	Eve-Day	Night-Day	Aft-Morn	Eve-Morn	Night-Morn	Eve-Aft	Night-Aft	Night-Eve
COMMUNITY C (ATLANTA, GA.)								
201	.64	2.88	-.26	.60	2.84	.86	3.10	2.24
202	-.51	5.64	.01	-.20	5.95	-.21	5.94	6.15
203	.60	4.65	-.78	-.19	3.86	.59	4.64	4.05
204	.67	1.03	.30	1.01	1.37	.71	1.07	.36
205	-1.78	.09	-.19	-1.71	.16	-1.52	.35	1.87
207	-2.41	-5.90	.56	-1.88	-5.37	-2.44	-5.93	-3.49
208	-.52	3.48	-.37	-.72	3.28	-.35	3.65	4.00
211	-1.44	.68	.22	-1.03	1.09	-1.25	.87	2.12
212	-.05	.53	-.39	-.19	.39	.20	.78	.58
213	-1.47	-.10	-2.68	-3.40	-2.03	-.72	.65	1.37
214	-.11	.87	-.47	-.75	.23	-.28	.70	.98
$\overline{X}$	-.58	1.26	-.19	-.77	1.07	-.40	1.44	1.84*
σ	1.06	3.06	.71	1.23	3.05	1.02	3.09	2.48
N	11	11	11	11	11	11	11	11

*Indicates mean value differs from zero at .05 level of confidence.

TABLE E-II DIFFERENCES IN ESTIMATED ANNOYANCE THRESHOLDS IN TERMS OF MAXIMUM A-WEIGHTED SOUND LEVEL (CONT'D)

Respondent	Eve-Day	Night-Day	Aft-Morn	Eve-Morn	Night-Morn	Eve-Aft	Night-Aft	Night-Eve
COMMUNITY D (ATLANTA, GA.)								
216	- 1.67	- .62	1.87	.04	1.09	- 1.83	- .78	1.05
222	.40	.12	1.02	1.09	.81	.07	- .21	- .28
223	.85	1.31	- 2.56	- 1.15	- .69	1.41	1.87	.46
224	.79	- .61	1.45	1.82	.42	.37	- 1.03	- 1.40
225	- 1.05	4.45	- 2.53	- 2.07	3.43	.46	5.96	5.50
226	- .56	- 1.85	1.35	.49	- .80	- .86	- 2.15	- 1.29
227	- 2.28	- 3.07	- .36	- 2.24	- 3.03	- 1.88	- 2.67	- .79
228	1.22	.42	- .11	1.16	.36	1.27	.47	- .80
229	.93	.47	.48	1.01	.55	1.49	1.03	- .46
230	2.43	1.94	.46	2.40	1.91	1.94	1.45	- .49
231	.77	2.09	1.36	1.00	2.32	- .36	.96	1.32
232	2.14	--	1.41	3.68	--	2.27	--	--
233	.04	4.07	- .78	- .43	3.60	.35	4.38	4.03
234	- 1.31	- .45	1.16	- .36	.50	- 1.52	- .66	.86
235	- .02	- .63	1.89	1.42	.81	- .47	- 1.08	- .61
237	.02	.70	3.11	.86	1.54	- 2.25	- 1.57	.68
238	.90	2.02	- 1.27	.25	1.37	1.52	2.64	1.12
239	.18	.87	.10	.69	1.38	.59	1.28	.69
240	- .83	.09	- 2.33	- 1.03	- .11	1.30	2.22	.92
$\overline{X}$	.16	.63	.25	.45	.86*	.20	.67	.58
σ	1.23	1.86	1.61	1.47	1.54	1.38	2.24	1.77
N	19	18	19	19	18	19	18	18
ALL RESPONDENTS								
$\overline{X}$	.50	.87	- .67	.07	.94*	.74	.96	1.06*
σ	2.55	2.36	2.79	2.38	2.18	2.90	2.57	2.11
N	46	29	46	46	29	46	29	29

*Indicates mean value differs from zero at .05 level of confidence.

TABLE E-III DIFFERENCES IN UNIT ANNOYANCE SOUND EXPOSURE LEVEL

Respondent	Eve-Day	Night-Day	Aft-Morn	Eve-Morn	Night-Morn	Eve-Aft	Night-Aft	Night-Eve
			COMMUNITY A (BURBANK, CA.)					
002	.63	--	- 2.71	- 1.21	--	1.50	--	--
004	.97	--	- 1.46	- .18	--	1.28	--	--
005	.86	--	- 1.31	.08	--	1.38	--	--
006	- .81	--	- .47	- 1.08	--	- .61	--	--
009	.08	--	- 2.85	- 1.81	--	1.05	--	--
010	- .05	--	- 1.85	- 1.50	--	.37	--	--
011	.17	--	- .23	- .03	--	.20	--	--
013	.47	--	- 1.27	- .14	--	1.13	--	--
014	.96	--	- .67	.88	--	1.55	--	--
015	.17	--	- 1.21	- .54	--	.67	--	--
$\bar{X}$	.34	--	- 1.41*	- .55	--	.85*	--	--
σ	.55	--	.87	.83	--	.69	--	--
N	10	--	10	10	--	10	--	--
			COMMUNITY B (BURBANK, CA.)					
016	- 2.05	--	1.21	- .92	--	- 2.13	--	--
017	- 1.59	--	.43	- 1.34	--	- 1.77	--	--
018	- .92	--	1.63	.75	--	- .87	--	--
019	- 3.80	--	- .06	- 3.03	--	- 2.97	--	--
021	- 1.57	--	.93	.05	--	- .88	--	--
024	- 2.68	--	.65	- 2.54	--	- 3.19	--	--
$\bar{X}$	- 2.10*	--	.80*	- 1.17	--	- 1.97*	--	--
σ	1.02	--	.59	1.46	--	1.00	--	--
N	6	--	6	6	--	6	--	--

*Indicates mean value differs from zero at .05 level of confidence.

TABLE E-III DIFFERENCES IN UNIT ANNOYANCE SOUND EXPOSURE LEVEL (CONT'D)

Respondent	Eve-Day	Night-Day	Aft-Morn	Eve-Morn	Night-Morn	Eve-Aft	Night-Aft	Night-Eve
COMMUNITY C (ATLANTA, GA.)								
201	.51	3.41	-.33	.32	3.22	.65	3.55	2.90
202	-.29	2.22	-.23	-.43	2.09	-.20	2.32	2.52
203	-.50	.06	-.28	-.75	-.19	-.47	.09	.56
204	.47	1.30	.30	.84	1.67	.54	1.37	.83
205	-2.14	2.16	-.49	-2.33	1.97	-1.84	2.46	4.30
207	-3.29	-6.56	.22	-2.68	-5.95	-2.90	-6.17	-3.27
208	.04	2.81	-.30	-.12	2.65	.18	2.94	2.77
211	-1.70	1.22	.12	-1.31	1.61	-1.43	1.50	2.92
212	.36	1.33	-.59	.12	1.09	.72	1.68	.97
213	-1.03	.75	-2.21	-2.59	-.80	-.37	1.41	-1.78
214	-.01	1.45	-.68	-.77	.70	-.09	1.38	1.47
$\overline{X}$	-.69	.92	-.41	-.88*	.73	-.47	1.14	1.61*
σ	1.23	2.65	.68	1.21	2.51	1.14	2.59	1.97
N	11	11	11	11	11	11	11	11

*Indicates mean value differs from zero at .05 level of confidence.

TABLE E-III DIFFERENCES IN UNIT ANNOYANCE SOUND EXPOSURE LEVEL (CONT'D)

Respondent	Eve-Day	Night-Day	Aft-Morn	Eve-Morn	Night-Morn	Eve-Aft	Night-Aft	Night-Eve
COMMUNITY D (ATLANTA, GA.)								
216	- 1.98	.08	2.68	.79	2.44	- 1.89	- .24	1.65
222	1.79	3.26	2.09	3.22	4.70	1.13	2.61	1.47
223	.65	2.00	- 2.25	- 1.23	.12	1.02	2.37	1.34
224	1.64	.80	2.12	3.14	2.31	1.03	.19	- .84
225	- .59	4.35	- 1.00	- 1.03	3.91	- .04	4.91	4.94
226	- 1.21	- 1.50	1.52	.01	- .28	- 1.51	- 1.80	- .29
227	- 2.85	- 3.99	- .30	- 2.71	- 3.85	- 2.41	- 3.55	- 1.14
228	.73	.66	1.23	1.33	1.26	.10	.03	.08
229	.33	.63	.67	.69	.99	.01	.31	- .30
230	2.50	2.60	.67	2.71	2.81	2.04	2.14	.10
231	.41	1.74	1.82	1.03	2.35	- .79	.53	1.33
232	1.20	--	1.39	2.47	--	1.08	--	--
233	.06	3.29	- .05	.11	3.33	.16	3.38	3.23
234	- 1.78	.86	1.79	- .40	2.24	- 2.19	.45	2.64
235	- .03	.16	2.91	2.22	2.42	- .69	- .50	.19
237	- .83	1.71	3.75	.18	2.73	- 3.57	- 1.02	2.55
238	1.07	2.26	.14	1.21	2.40	1.07	2.26	1.19
239	.15	3.46	1.27	1.69	5.00	.43	3.74	3.31
240	- .43	- .20	- 3.64	- .25	- .03	3.39	3.62	.23
$\bar{X}$	.07	1.23*	.88	.80*	1.94*	- .09	1.08	1.23*
σ	1.34	1.99	1.79	1.58	2.06	1.70	2.19	1.61
N	19	18	19	19	18	19	18	18
ALL RESPONDENTS								
$\bar{X}$	- .34	1.11*	.07	- .15	1.48*	- .22	1.10*	1.37*
σ	1.36	2.22	1.57	1.54	2.28	1.53	2.31	1.73
N	46	29	46	46	29	46	29	29

*Indicates mean value differs from zero at .05 level of confidence.

TABLE E-IV COMPARISON OF WEIGHTING FACTORS DERIVED FROM ALTERNATIVE METHODS OF ANALYSIS

Analysis Method		Eve-Day	Night-Day	Aft-Morn	Eve-Morn	Night-Morn	Eve-Aft	Night-Aft	Night-Eve
A-Max Threshold									
	$\overline{X}$	.50	.87	- .67	.07	.94*	.74	.96	1.06
	σ	2.55	2.36	2.79	2.38	2.18	2.90	2.57	2.11
SEL Threshold									
	$\overline{X}$	1.02*	1.63*	- .65	.66	1.72*	1.32*	1.79*	1.47*
	σ	2.93	2.79	3.13	2.80	2.48	3.39	3.01	2.20
Unit Annoyance SEL									
	$\overline{X}$	- .34	1.11*	.07	- .15	1.48*	- .22	1.10*	1.37*
	σ	1.36	2.22	1.57	1.54	2.28	1.53	2.31	1.73

*Indicates mean value differs from zero at .05 level of confidence.